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Figure 3-2
Summary of Reclamation Projects

(1) Project Sponsor	(2) Project Name	(3) Location	(4) Type of Remediation	(5) Project Timeframe	(6) Funding (incl. in-kind match)	(7) Improvements (actual or anticipated)
Sunnyside Gold Corp.	Lead Carbonate Millsite	Gladstone on bank of S. Fork of Cement Creek	Removal of 27,000 yards of tailings from streambank	Completed 1991	SGC: $163,000	Reduce loading of metals and erosion transport of tailings
Sunnyside Gold Corp.	Mayflower Mill – Tailings Ponds #1, #2 and #3	Mayflower Mill complex near Boulder Creek and Animas River	Re-contour inactive tailings ponds and cap. 625,000 yards of tailings and overburden moved.	Completed 1991-1992	SGC: $1,755,000	Mined land reclamation –reduce loading of metals and erosion transport of tailings
Sunnyside Gold Corp.	Lake Emma Sunnyside Basin	Sunnyside Basin headwaters of Eureka Creek	Fill mine subsidence, remove mine waste and re-contour disturbances. 240,000 yards moved.	Completed 1991-1993	SGC: $911,000	Mined land reclamation and reduce loading of metals
Sunnyside Gold Corp.	American Tunnel waste dump	Gladstone on bank of S. Fork of Cement Creek	Remove 90,000 yards of waste dump and underlying historic tailings	Completed 1995	SGC: $766,500	Mined land reclamation and reduce loading of metals and erosion transport of tailings
Sunnyside Gold Corp.	Eureka Townsite	Eureka on banks of Animas River and S. Fork of Animas and in flood plain	Remove 112,000 yards of tailings	Completed 1996	SGC: $843,000	Reduce loading of metals and erosion transport of tailings
Sunnyside Gold Corp.	Gladstone	Cement Creek treatment at Gladstone	Divert and treat Cement Creek to mitigate any short term impacts of reclamation projects	8/96-5/99, 11/99-12/99	SGC: $901,000	Reduce loading to Animas River to offset any short term impacts which could occur as a result of reclamation
Sunnyside Gold Corp.	Boulder Creek Tailings	Flood plain of Boulder Creek and the Animas River	Remove 5700 yards of tailings	Completed 1997	SGC: $32,500	Reduce loading of metals and erosion transport of tailings
Sunnyside Gold Corp.	Ransom adit	Eureka townsite above old mill foundation	Bulkhead seal to stop deep mine drainage and reclaim portal	Completed 1997	SGC: $85,400	Restore hydrologic regime and reduce rate of ore oxidation by placing mine workings under water to reduce metal loading

(1) Project Sponsor	(2) Project Name	(3) Location	(4) Type of Remediation	(5) Project Timeframe	(6) Funding (incl. in-kind match)	(7) Improvements (actual or anticipated)
Sunnyside Gold Corp.	Gold Prince mine waste and tailings	Headwaters of Placer Gulch	Bulkhead seals to stop deep mine drainage. Consolidate mine waste and tailings (moved 6000 yards) and construct upland diversions	Completed 1996-1997	SGC: $151,000	Reduce exposure to water to reduce metal loading
Sunnyside Gold Corp.	Longfellow-Koehler	Headwaters of Mineral Creek near top of Red Mtn. Pass	Remove Koehler dump (32,100 yards), consolidate Junction Tunnel dump and Longfellow dump and cap. Capture adit drainages. Construct diversions. Feasibility study of wetland treatment of Koehler drainage.	Completed 1996-1997	SGC: $580,000	Reduce metal loading and erosion transport of mine waste
Sunnyside Gold Corp.	Pride of the West tailings	Howardsville near confluence of Cunningham Creek with Animas River	Remove 84,000 yards of tailings	Completed 1997	SGC: $490,500 TUSCO: $14,000	Reduce metal loading and transport of tailings by erosion
Sunnyside Gold Corp.	Alkaline injection	Sunnyside Mine	Inject 652 tons of hydrated lime into the Sunnyside Mine pool to provide increased alkalinity and improve initial mine pool conditions	Completed 1996-1997	SGC: $313,000	Improve initial conditions as water table is restored through bulkheading to stop mine drainage
Sunnyside Gold Corp.	Mayflower Upland Hydrological Control	Mayflower Mill and TP #1 area near Silverton	Capture and divert three upland drainages that were going sub-surface up-gradient of the mill and TP #1 facilities	Completed 1998-1999	SGC: $186,000	Minimize potential for contact of runoff with tailings and reduce potential for metal loading
Sunnyside Gold Corp.	TP #4 drainage modification	Drainage ditch between Hwy. 110 and TP #4 near Silverton and Animas R.	Install lined diversion ditch to capture surface runoff and prevent infiltration through tailings material	Completed 1999	SGC: $72,000	Minimize potential for contact of runoff with tailings and reduce potential for metal loading
Sunnyside Gold Corp.	TP #4 upland groundwater diversion	Up-gradient from TP #4 near Silverton	Capture groundwater and divert around tailings impoundment	Completed 1993-1995, 1999	SGC: $409,000	Minimize potential for contact of groundwater with tailings and reduce potential for metal loading

(1) Project Sponsor	(2) Project Name	(3) Location	(4) Type of Remediation	(5) Project Timeframe	(6) Funding (incl. in-kind match)	(7) Improvements (actual or anticipated)
Sunnyside Gold Corp.	Sunnyside Mine hydraulic seal project	Sunnyside Mine	Bulkhead placement in Sunny-side Mine to restore hydrologic regime to approximate pre-mining and eliminate drainage from adits (6 bulkheads)	Completed 1992-1996	SGC: $2,346,000	Place mine workings under water to reduce oxidation, restore groundwater movement around mine workings and eliminate need for perpetual water treatment
Gold King Mines Corp	Gold King	Gladstone, N. Fork of Cement Cr.	Hydrologic controls for workings and mine waste	1998	Gold King: $117,300	Reduce metal loading to Cement Cr.
Silver Wing Mining Co.	Silver Wing	Animas river, about 1.5 mile above Eureka	Collect AMD, hydrological controls	1995	Silver Wing $7,000	Remove AMD from dump, reduce metals loading
Silver Wing Mining Co.	Silver Wing	Animas River, about 1.5 miles above Eureka	Anoxic Drain, settling pond, bioreactor	1999-2000	319 Funds: $216,000 Silver Wing: $144,000	Reduce metal loading to the Animas River.
San Juan RCD / (ARSG)	Carbon Lakes Mine Dump	Headwaters of Mineral Cr. East of Red Mtn. Pass	Removal of 1,900 cubic yards of waste rock from stream channel	Phase 1 – completed 1999	319 Funds: $72,000 ARSG match: $62,800	Reduce loading of metals especially Cadmium, Copper, Iron, Lead, Manganese, and Zinc
San Juan RC & D (ARSG)	Carbon Lakes Mine Waste Phase II Part 1	Headwaters of Mineral Creek East of Red Mtn. Pass	Complete removal of waste rock from stream channel	2000 season	319 Funds: $78,500 ARSG Match: $52,300	Reduce loading of metals to Animas River
San Juan RC & D (ARSG)	Carbon Lakes Mine Waste Phase II Part 2	Kohler Tunnel	Reduce flows from Kohler Tunnel by reducing infiltration into San Antonio Mine Workings	2000 season	319 Funds: $66,900 ARSG Match: $44,600	Reduce metals loading to the Animas River by reducing infiltration of water into old mine workings
Mining Remedial Recovery Co.	Sunbank Group	Placer Gulch	Anoxic drain, settling pond, waste consolidation, bulkhead	1995	319 Funds: $58,000 MRRC: 38,500	Raise pH from draining adit, reduce metal loading from adits and mine waste
Salem Minerals	Mammoth Tunnel	N. Fork Cement Cr.	Settling ponds for mine drainage	1999	319 Funds: $10,050 Salem: $6,700	Focused on reductions of iron to Cement Cr.

(1) Project Sponsor	(2) Project Name	(3) Location	(4) Type of Remediation	(5) Project Timeframe	(6) Funding (incl. in-kind match)	(7) Improvements (actual or anticipated)
Office of Surface Mining	Galena Queen	Prospect Gulch	Waste consolidation & hydrological controls	1998	Office of Surface Mining: $10,000	Reduce surface water leaching of toxic metals
BLM	Forest Queen	Eureka	AMD treatment	1997-98	$275,017	Reduced metals input into Animas
BLM	Mayday	Cement Creek	Storm water controls	1998	$10,000	Reduce surface water leaching of toxic metals
BLM	Mayday	Cement Creek	Cap dump	1999	$54,360	Reduce surface water leaching of toxic metals
BLM	Joe & John	Prospect Gulch	Mine drainage collection and diversion	1998	$39,980	Collect AMD for later treatment project development
BLM	Lark Mine	Prospect Gulch	AMD collection	1999	$19,725	
FS					$0	

ATTACHMENTS

Attachment 1	Animas River Field Data form
Attachment 2	Chain-of-Custody form
Attachment 3	SOP for filtration
Attachment 4	SOP for flow measurement

Attachment 1 Animas River Field Data form

Attachment 2 Field Sample Record

Attachment 3 Chain-of-custody form

Attachment 4 SOP for filtration

Filtration will be done in accordance with these "Standard operating procedures for the filtration of water samples" (attachment 4), which was originally taken from the "Quality Assurance Project Plan for the Colorado Nonpoint Source Monitoring Program", but has been modified for site-specific considerations, and advances in technology.

The methods described in this standard operating procedure document will focus on a "syringe" filtering procedure.

EQUIPMENT

1. 60 cc syringe w/Luer-Lok tips.
2. Swinnex disc filter holders, 47 mm diameter, polypropylene with silicone 0-rinqs.
3. Cellulose Acetate 47mm diameter, .45 um pore size filters.
4. Deionized water used for rinsing.
5. Teflon coated or nonmetal forceps.
6. Pre-acidified 250 ml bottles.
7. Precleaned and rinsed sample container. (1 liter bottle)

SITE AND SAMPLING CONSIDERATIONS

Several considerations should be taken before an actual sample is obtained.

1. If more than one site is going to be sampled, each site should have it's own collecting and filtering equipment. This is not always practical where there are numerous sites to be monitored. In this case, 2 or more sets of equipment are used, one set at suspected contaminated sites, and one set for suspected clean sites. This technique reduces the possibility of contamination going from a highly polluted site to a relatively clean site. If one set of collecting equipment is going to be used, sampling should progress from the clean areas to the contaminated areas. Thorough rinsing is the key to uncontaminated samples.

3. If sampling several locations on the same waterbody, a "downstream-to-upstream" approach is be used. This ensures that any substrate constituents which may be stirred up during the sampling procedure are going to flow downstream as you work upstream and will not be introduced at the next station.

SAMPLE PREPARATION

All sampling equipment must be cleaned and rinsed before any sample collection may take place. The EPA will supply all sampling containers and preacidified 250ml metals containers which are cleaned under the laboratory's Quality Assurance Plan.

The filter holders and syringes must also be clean. Disassemble the filter holder apparatus. The O-rings on the upper and lower section of the holders are soaked in deionized water for 24 hours. The filter holders and syringes must be soaked in a 5% nitric acid, 95% deionized water mixture for 24 hours. Then rinsed with deionized water prior to use.

QUALITY ASSURANCE

A duplicate sample will be collected at 20% of the sampling stations for QA purposes. The duplicate is taken out of the same container as the stream sample. Rinsing of the filter holder and a new filter are placed in the filter holder using the procedures described. The duplicate sample will be labeled "FILT DUP", along with the site name or number, date, time, and name.

A "BLANK" sample of the deionized water used in rinsing is taken at the end of each sampling day. The same rinsing and filtering procedure is used for the sample.

FILTRATION PROCEDURES

1. Rinse a 1 liter neutral (unpreserved) container with the water to be sampled at least three times before gathering a sample to be filtered on-site. Fill container and cap for later filtering. Filtering must be done no later than a half an hour after collection.

2. Locate a dust free environment as possible, ideally, a mobile or camper lab to set up and filter.

3. Rinse the syringe and filter holder with deionized water.

4. Place a clean filter in the filter holding apparatus using non metal (clean and rinsed) forceps.

5. Run 50 ml of deionized water through the filtering apparatus using the syringe. Discard filtrate.

6. Run 50 ml of sample water through the filtering apparatus using the syringe. Discard filtrate.

7. After being completely rinsed and flushed, the sample may be filtered into the preacidified container. Do not rinse the preacidified container. If the filter begins to clog, do not force the sample through the filter, but replace with a new filter after following the rinsing procedures.

8. Fill the sample container to the rim of the preacidified bottle. The container has a predetermined amount of preservative for a full sample.

9. Label bottle with the site, time, date and sample type, i.e.
"Filtered", "Filt Dup", or "Filt Blank".

10. Immediately and thoroughly rinse all filtering equipment with deionized water before it dries and place in a zip lock storage bag for transport to the next site.

11. Upon completion of a sampling run, the filtering apparatus should be taken apart and soaked in a mixture of 5% nitric acid and 95% deionized water for 24 hours as described above.

MODIFICATION

Disposable encapsulated .45 micron filters (Gelman Sciences ion chromatography arcodisc) may be used in place of the filter in the Swinnex filter holder. In this case, filters are rinsed with approximately 10 ml of the water to be sampled before the sample is collected. If the filter clogs, a new disposable encapsulated filter will be used. The new filter will also be rinsed with approximately 10 ml of the water to be sampled before continuing with the sample collection.

Attachment 5 Flow Measurement

"Standard operating procedures for the collection of flow measurements" that has been adapted from the Quality Assurance Project Plan for the Colorado Nonpoint Source Monitoring Program

FLOW MEASUREMENTS:

OVERVIEW:

Discharge measurements are a vital part of water quality sampling. Discharge is used in constituent loading formulas, dilution factors, and discharge rates, as well as other aspects in which the rate of flow in needed. This Standard Operating Procedure will focus predominantly on instantaneous flow measurement procedures for open channels as needed in water quality sampling protocols.

TYPES OF FLOWMETERS

There are different types of flowmeters available for use, such as the Pygmy, Marsh-McBirney, and Price AA meters. Although they operate differently, they provide comparable results. Follow the individual unit's manufacturer's instructions.

CALIBRATION SCHEDULE

Sampling personnel should calibrate their flowmeters at least once per year.

QUALITY ASSURANCE USING DIFFERENT FLOWMETERS IN A STUDY

In detailed and intense studies, in which many crews are involved, a quality assurance check should be done at the beginning of each sampling day to ensure that proper and comparable flow readings are being taken. This involves eliminating as many different factors as possible. Use of the same type of meter is ideal but not always the case. Steps to be taken include:

1. Taking flow measurements at an identical location.

2. Using the same cross section intervals.

3. Each crew shall use the same technique they are going to use in the field to collect their flow measurements.

4. Field notes and field forms should be the same or similar for use in the same study. (See attached discharge measurement form)

5. Final flow measurements should compare to within 10% of

each other. Make any necessary adjustments and duplicate flow procedures until within 10%. (See discharge calculation section). Follow flowmeter's manufacturer's instruction manual. Marsh McBirney instruction manual attached.

SELECTION OF STREAM SITE FOR FLOW READING

Selecting a cross section of a stream or channel for flow measurement requires careful consideration.

1. Select a stretch in which the stream is not turbulent, or fluctuating from side to side. Preferably a glide type area.

2. Suspend a measuring tape, which is calibrated in feet and foot-tenths, one foot above the stream or channel, perpendicular to the flow.

3. Measurements will be made perpendicular to the flow, facing upstream. Measurements will be in feet/second.

4. If depth is less than 2.5 feet, the flow measurement will be taken at 60% of the depth, from the surface. This is the standard setting of the top setting rod. If over 2.5 feet in depth, a two point method is used, which is the average velocity at a 20% and 80% depth measurement. This is done by calculating the 20 and 80% depths and placing the electromagnetic sensor (Marsh-McBirney Model) on the top setting rod, at the distance from the surface.

5. Try to avoid areas where there are dead pools of water such as behind large boulders.

6. Take a minimum of 10 measurements within the stream channel, including distance from bank, depth, and velocity. The more segments you use the better the result. Also record the bank distances. (See flow data sheet attached). If the difference in velocity between two adjacent segments is greater than 10%, the segments should be smaller.

7. Follow the manufacturer's instructions for individual types of flowmeters.

DISCHARGE CALCULATION

Stream Profile:

W4 W5 wx

Dx

where;

W = Measured width of segment
V = Measured velocity of segment
A = Calculated area of segment
D = Measured depth of segment
Q = Calculated flow of segment

Calculate the,area of each segment by: **(Dx +** D-') / 2 * (Wx + Wx-') / 2 = A' Calculate the average velocity of the segment:

V-9 = (Vx + Vx-') / 2

'Then calculate the flow of each secjment by:

Ax * vx = Q x

Sum the flow of the segments for the total flow.

Ql + Q2 + Ql + . . **+Qx = Qtt**

the process. Two used sodium thiosulfate leaching to recover silver. (CBM 1898 and Henderson 1926)

C. ENVIRONMENTAL ASPECTS

Mining's environmental impacts during this period were primarily due to a greatly expanded scope. Techniques were similar to prior periods but on a larger scale through increasing mechanization. Waste dumps from the sorting houses became large, some exceeding 50,000 tons. Water drainage became more of a problem as longer tunnels impacted groundwater levels. When shaft mining was done, water infiltrating into the mines had to be pumped out. In the nearby Red Mountain Mining District, acidic water was a major problem and was commented upon in early literature(citation). In Silverton, grossly acidic water appears not to have been a major problem. Water infiltrating the "filled" type stopes could potentially pick up metal contamination however. By the end of the period many mines were operated through long lower tunnels, which tended to drain the ground water down to that level leaving upper mine workings relatively dry. Some of these tunnels such as Gold King's reached several thousand feet in length.

The great increase in milling during the period did have a major impact on surface water quality. The mills produced a muddy slurry waste product called "tailings". These tailings were usually discharged directly into a nearby stream or river. Sometimes they were discharged haphazardly on the ground or riverbanks. Stamp mill tailings were like coarse sand. The ore particles were soft and would tend to slime making recovery difficult for the Wilfley Tables. There would be a tendency for the coarse sands to settle out more quickly in the river gravels, while finer material would stay suspended for long distances. These mills could recover 60% to 80% of metals in the ore such as gold, silver, and lead. Zinc, iron pyrite, and a portion of the copper were not recovered by gravity mills. (Niebur 1986) Thus, significant amounts of metals were left in the tailings, and particularly the very fine "slime" particles where they could be widely distributed into the aquatic environment.

At Silver Lake, the first mill was located beside the lake itself, and deposited tailings into the lake. About 500,000 tons were reported to be in the lake by 1903. (Neibur 1986) No mercury or other chemicals were used at this mill. (Ransome 1901) Improvements in milling technology resulted in about 400,000 tons of these tailings being pumped out of the lake between 1914 and 1919 for reprocessing in a new mill along the Animas River. Although more metals were removed from the tailings, 500 tons per day of residues were then discharged directly into the Animas River near the mouth of Arrastra Gulch. (Neibur 1986)
Incorporate 1902-03 Durango-Silverton pollution debate and Durango's change to different water source.

Chemical reagents were not used in the typical gravity concentration mill, although mercury coated amalgamation plates were common. Mercury could be lost by physical attrition off the plates. Due to its high value, mercury traps and other recovery devices were incorporated into the mill to keep mercury losses low. Also particles of amalgam could be recovered by the concentrating tables. (Taggart 1927) This may help explain why mercury contamination has not been generally detected in the watershed. Bill, we seldom ran Hg. Then too, detection limits should have been much lower (like 10ppt) We did get a .1ppb hit at A72. But then we got several .6 to 27 ppb dissolved hits at mine adit discharges and possibly a spring or two. It's definitely around but not much at the gauges and probably not a result of milling. I need to check the EPA's sediment data--I think it shows up now and then. Sodium thiosulfate was used in two short-lived "lixivation" mills but this is not an acutely toxic reagent, being the same as photographic "hypo" developer solution.

Total tonnage for the period 1890 – 1914 is estimated at 3,898,971 tons with a large majority of the tonnage being discharged as tailing. Henderson reported only 78,000 tons crude ore shipped 1909-1923 by comparison.

PERIOD III – THE EARLY FLOTATION ERA 1915-1934

A. MINING DEVELOPMENT & PRACTICES

In Europe, World War I developed into a war of attrition that consumed huge quantities of metals. The United States entered the war in 1917 and an already brisk wartime economy boomed. Base metals prices soared as the war continued to expand. (Henderson 1926) Gold and silver were of lesser importance at this time. Improvements in both smelting and milling, coupled with wartime demand made zinc ores a marketable commodity for the first time (Bird 1986). Mines with zinc, such as the Sunnyside expanded while those without closed such as the pioneering Silver Lake mine.

The flotation mill could do much of the separation formerly done by hand sorting or selective mining of the ores. Mining practices thus began a major shift to larger scale "bulk" mining methods and away from more selective lower tonnage methods. The new mining method was called "shrinkage stoping". Here the entire vein was mined, instead of only the best part. When the stope was completed all the broken ore was removed from the mine leaving a large void. In the "cut and fill" stope, the void was left full of low grade or waste material. No ore sorting was done and everything was milled. Average ore grade decreased, but so did the cost of mining and milling as tonnages increased and unit costs decreased. This was to become the dominant trend of mining throughout the twentieth century both in Silverton and worldwide.

Other technological changes contributed to this increase in tonnage. Larger, more efficient compressed air drills replaced the early types. "Wet" drills increased productivity by reducing dust and improving working conditions for the miners. Mines continued to increase in length, depth, and vertical extent. The Sunnyside became the largest producer in 1916. By 1917 its daily production increased to 500 tons. In 1918, 600 tons per day was reached and by 1927 over 1,000 tons per day was achieved. (Bird 1986) Wartime prices also saw many small mines open and a new smelter even operated during the war years to treat pyritic copper ores from Red Mountain.

High metal prices caused by the war were unsustainable, and in 1921 - 1922 a sharp recession hit the country. Mining in Silverton collapsed. In 1921 total production was a mere 1,100 tons versus over 200,000 tons mined in 1920. (Henderson 1926) Mining recovered in 1923 with the re-opening of the Sunnyside but the character of the industry changed permanently. Many small and medium sized mines closed for good, along with some older large mines such as Gold King in 1925. By 1930,only two mines would dominate production for the next 70 years, with small mines playing a more secondary role. By the late 1920's some new mines were begun as the national economy grew, notably the Shenandoah-Dives, Buffalo Boy, and Little Nation. But metals prices again collapsed with the onset of the great Depression in 1930. The Sunnyside closed in September 1930 leaving the one-year old Shenandoah-Dives mine as practically the only major producer for the next 23 years. (Chase 1952)

A. MILLING DEVELOPMENT & PRACTICES

By 1914 milling technology was being revolutionized by the introduction of ball mill grinding and froth flotation for concentrating ores. The sudden and widespread impact of this technology cannot be over emphasized. (Rickard 1932) Instead of coarsely pulverizing ores with crude stamps, high capacity wet grinding with steel balls in a rotating drum made a more uniform and finer product. Early flotation used bubbles in an acidified pine-oil/water mixture to float off and separate the valuable mineral particles from the worthless quartz. More importantly for Silverton, the process could separate zinc from the lead and copper, and worked well on the troublesome "slimes". In addition new electrolytic smelting processes made the zinc concentrates produced by flotation marketable at last.

The first large scale mills for lead-zinc ores were built in Butte, Montana in 1914 using the patented Minerals Separation Syndicate process. (Rickard 1932) Stamp mills and Wilfley tables quickly became obsolete for primary milling of base metal ores. Silver Lake and Gold King added experimental flotation sections in 1914 with Sunnyside trying it in 1915. (Henderson 1926) It worked so well at Sunnyside the Terry family sold controlling interest in the mine to the US Smelting and Refining Company. This large corporation had the financial resources to build a huge "state of the art" 750 ton per day flotation mill at Eureka in 1917. With it up to 90% of the minerals could be recovered, including zinc as a separate concentrate. Tailings now had less metal in them, but there were more tailings produced as tonnage expanded to 1,100 tons per day in the 1920's. Tables were still used in the new Sunnyside mill but were of secondary importance. (Taggart 1927) The new mill was the first large lead/zinc flotation mill in the state and one of the first in the nation. (Bird 1986) Most of the gravity/stamp mills remaining in the district were closed by the 1921 recession, or soon thereafter and never reopened. Tailings were discharged to nearby streams during this era?

B. ENVIRONMENTAL ASPECTS

Mining continued the trend toward larger and more extensive workings, with more potential impact on groundwater hydrology. Very long tunnels such as the Gold King and Frisco were nearly a mile in length. Significant localized drainage of groundwater was now occurring with resultant potential for acidic or metal laden discharge into the creeks. Improved milling gave some indirect benefits during the period. Low-grade and zinc bearing ore was less commonly left in stopes or on dumps where it could contact the environment, instead it was being milled.

Flotation milling on the other hand had an increasing impact on the Animas River. Ball milled tailings were much finer than the old stamp mill tailings. While the tailing contained less metal per ton, milled tonnage increased, yielding a net increase in tailing being deposited. The now finer tailings traveled farther and began to elicit serious, formal complaints from downstream water users in Durango and New Mexico. Sometime in the late 1920's downstream water users sued the Sunnyside mine's owner, US Smelting over the Eureka Mill tailing pollution. (USSM 1930) The main issue was sedimentation of irrigation ditches, not chemical contamination. (which could have been exaserbated by overgrazing) It is unclear if the case was actually tried, but the company prepared a vigorous defense. It hired Durango assayer A.P. Root to take weekly samples of the river, to be taken in Durango from March through September 1930, when the mine and mill closed. These samples were stored under seal for the next two years as legal wrangling continued. Root's field notes survive, and the river was typically described as "gray and turbid" during normal and low water flows. During high flow, the tailing's gray color was obscured by natural sedimentation. (Root 1930) Mining companies at the time typically argued these sediments were not harmful to fish or agriculture but the attitudes of the courts and the public were changing. (Smith 1987)

The oil flotation process used various chemical compounds to make the process work, but their environmental impact is difficult to assess at this time. In the early Minerals Separation process, the mill water was acidified with dilute sulfuric acid and pine-oil was added as the frothing reagent. Shenandoah used this pine-oil process for the first few years of their operation. Precisely what Sunnyside used in the 1918-1925 period is unknown, but lead/zinc mill practice at the time used alkaline solutions rather than acidic. The 1926 mill circuit and reagents are described in detail in Taggart's Handbook of Ore Dressing, 1927. Reagents included small amounts of coal tar, creosote, naphthalene, pine oil, and the new potassium xanthate as the main frothing reagents. Large amounts of sodium carbonate (soda ash) were used to raise the pH. The xanthate chemicals, an alcohol-like liquid, were patented in 1925 and are the basis of modern flotation, completely supplanting oil-flotation within a few years. (Rickard 1932)

It is worth noting today that in contrast to districts such as Telluride and Cripple Creek, there is no evidence that cyanide milling for gold was ever done in San Juan County, due to its chemical incompatibility with zinc and copper in the ores. Shenandoah-Dives' General Manager, Charles A. Chase had experience with cyanide milling during his prior work in Telluride where the toxic effects of cyanide tailings on the San Miguel River were recognized at the time, but it was never tried at Shenandoah. (S-DM Co *Reports*) probably should not abbreviate this

Total tonnage mined in the period 1915 – 1934 is estimated at 3,715,737 tons with nearly all of that being milled and entering the river as tailings.

PERIOD IV. THE MODERN FLOTATION ERA 1935 -1991

A. MINING DEVELOPMENT & PRACTICES

The Depression was a very difficult time for base metal mines. Declining industrial production saw the lowest prices of the century for silver, lead, copper, and zinc. Gold was an exception when the government devalued the dollar in 1934 by raising the price of gold 75% from its long time $20 per ounce level to $35 per ounce. All gold now had to be sold to the US Government or its authorized dealers, a regulation that lasted until 1971. (Smith 1987) This sparked a renewed interest in gold mine exploration but had no major impact on new San Juan County production due to the scarcity of gold ore in the district. It did help to keep Shenandoah-Dives, a low-grade gold mine, solvent and stimulated re-openings at the nearby Camp Bird in Ouray and several Telluride mines, later called Idarado.

Shenandoah survived by reducing per ton unit costs, chiefly by increasing tonnage mined and by improving the mill. Starting at 300 tons per day the mine soon changed to large shrinkage stoping and increased production to 600-700 tons per day. Virtually every ton of rock broken was milled. As base metal prices slowly recovered in the late 1930's, a few small high grade lead-zinc mines were developed such as the Pride of the West, which built its own 70 ton/day mill at Howardsville. The size and extent of the mines continued to increase. Shenandoah reached a vertical extent of over 2,500 feet by 1941 and horizontal extent of over 7,000 feet by 1948. (S-DM Co *Reports*)

The Sunnyside re-opened for about 18 months in 1937-38, but it closed due to sagging prices, high operating costs, and "excessive water which forced the... owners to abandon the work". (Standard Metals 1960) Soon the impact of the Second World War began to affect the industry. When America entered the war after Pearl Harbor, the country was desperately short of zinc and other base metals. In 1942 the government closed all gold mines so that scarce mining labor and resources could be focused on base metal production. Shenandoah-Dives, a nominal gold mine, was ordered closed by the War Production Board. Chase and Silverton leaders put political pressure on the WPB through Colorado's governor and congressional delegation. The WPB actually re-wrote its national regulations in such a way as to permit Shenandoah-Dives to meet the new criteria. (*Mining World* 1942) The mine and Silverton were saved, along with the narrow-gauge train, which is now the king-pin of the tourism economy in the region.

As milling technology improved and wartime demand increased, Shenandoah and other mines began to re-mine old underground stope "fills" and surface dumps left by the old timers. In Dives Basin, Shenandoah recovered over 100,000 tons of dumps left by turn of the century ore sorting operations. (S-DM Co *Reports*) This "dump recovery" was widespread in the county during World War II and the Korean War when surplus four-wheel drive trucks became available. Government policy further stimulated mining when it began to pay bonus price subsidies called "premiums" for every pound of metal mined. Road building and exploration were also subsidized by the US Bureau of Mines through the Defense Minerals Exploration Act (DMEA). The Reconstruction Finance Corporation (RFC) actively loaned money for mining projects and the Metals Reserve Corporation bought metals and ores directly for strategic government stockpiles. These programs survived into the early 1960's.

With such favorable economic and government policies, upwards of dozens of long dormant mines were re-opened. Ore was shipped to Shenandoah's mill for processing and when its capacity was reached, by rail to the Golden Cycle mill in Colorado Springs. These mines were small, often mining only a few tons per day. Shenandoah remained the main producer at 600 tons per day with about 100 tons per day of "custom ore" being milled in summer months from the small producers. The Pride of the West, Highland Mary, and Lead Carbonate built or expanded mills and increased production during the war. Production would have increased more during the war, except for the shortage of labor. This labor shortage was the reason the Sunnyside never reopened during the war, despite large zinc reserves.

Shenandoah continued steady development of its property and the adjacent Silver Lake mine into the early 1950's. Metals prices again declined after the 1952 election of Eisenhower and in 1953 the new Congress withdrew Korean War price supports for lead-zinc. Production ceased in March of 1953, which had the effect of closing most of the remaining small mines who were dependent on Shenandoah's mill for processing. A government DMEA exploration grant kept the mine alive for a few more years though without production. (USBM-DMEA 1955)

In 1959 a new company, Standard Metals Corporation, bought the Shenandoah and its mill and began work to extend the old Gold King Tunnel at Gladstone another mile under the long dormant Sunnyside. Improved mining technology now made very long tunnels feasible. The work is described in the 1960 Standard Metals Corporation *Annual Report*: "The [American] Tunnel was driven in order to provide an economical means for removal of ore as well as drainage. The original schedule for reaching the Washington vein was January 1961. This has been accomplished in spite of a water flow of 3,000 gallons per minute encountered from the 9,000 foot mark. .... Prior to driving the American Tunnel, the drainage of eight million gallons of water in the Sunnyside mine workings was ... a potential major problem. Fortunately the tunnel intersected a fault zone with fissures resulting in a gradual drainage of the old workings. The water level has been dropping an average of more than three feet per day in the old Washington Incline [shaft]. At this rate, when the raise is ready for the breakthrough the volume of water remaining in the upper level will be negligible." The tunnel's ability to drain the workings proved successful, but would come to haunt later owners. Production from the Sunnyside through the 11,000 foot long tunnel began in August, 1962 and continued at 700 tons per day, increasing to 1,000 tons per day for a few years in the late 1970's.

Unexpected gold discoveries kept the mine going long after other similar base metal mines in the state closed.

Other than the Sunnyside, relatively little new mining was done after 1953 other than a few small mines that operated intermittently and some major exploration projects. In 1967 a Texas oil company called Dixilyn began a large project at the Old Hundred mine. It found little ore but constructed over 15,000 feet of new tunnels (where-what district perhaps?). Significant drainage was also encountered as at Sunnyside, but of better quality. About 20,000 tons of dumps and ore were milled at the expanded Pride of the West Mill. High gold and silver prices in the late 1970's and early 1980's caused another increase in exploration activity around Silverton. A few new access tunnels were built but again, little or no ore was developed. Several old mines were explored but prices did not maintain a high level long enough to sustain major new mining development. Major mining was confined to the Sunnyside, which benefited from the high gold prices. Higher prices did mean mine dumps at Lake Emma and other locations were shipped and milled.

In the late 1970's new surface reclamation laws in Colorado began to affect ongoing mining operations. In 1983, aggressive legal action under Superfund against Newmont Mining's nearby Idarado Mine in Telluride caused several major US and Canadian mining companies operating in San Juan County to quickly terminate leases and activities. After 1984 no major US mining company initiated any new activity in San Juan County due in large part to the underlying uncertainty of similar legal action. The continued exception was the Sunnyside, which was purchased by Canadian based Echo Bay Mines in late 1986 after the bankruptcy of Standard Metals Corporation. By 1991 **its reserves were exhausted** and the property went into reclamation. Low metal prices coupled with increasingly complex environmental regulations resulted in a cessation of mining and exploration activity after 1991, following a pattern similar to other mining districts in Colorado. This is really arguable. One could as easily say it was due to another major developmental change in the industry--open pits, leaching, and mechanization.

B. MILLING DEVELOPMENT & PRACTICE

In 1935 the Shenandoah-Dives Mill was the only milling operation in the watershed. As a result of both downstream complaints and management's personal philosophy, the first successful steps were taken to prevent major water pollution by mill tailings. When the mill was built in 1929, Shenandoah's remarkable manager Charles A. Chase with the support of concerned stockholders intended *not* to discharge tailings into the river at all. Instead special tanks and machinery were installed to settle the tailing and haul the sand back up the tramline, where it would be dumped as a surface pile keeping it out of the river. Mill water would be filtered and recycled. Unfortunately the equipment did not work, and being nearly broke, the company reluctantly discharged tailings into the Animas River as mills had before. (Smith 1987) In 1935 Chase learned of a novel method of tailing impoundment being used at Butte, Montana. The technique was tried and after several trials and changes was found both economic and effective. By 1936 nearly all their tailing was being retained in ponds, and out of the river. (Chase 1938)

In a tailing pond the sands are used to build up a dam while the slimes and water settle behind the dam. As it settles, the water clears, and can be decanted out into the river through pipes, devoid of most mineral laden particles. Variations on this method were used until the end of milling in 1991. While effective, the system was not perfect and the hillside was not conductive to pond stability. The sand wall on Pond #1 collapsed in 1947 and again in 1975, due to ice build up in the sand wall, the latter event causing abandonment of the pond. These accidents caused thousands of tons of tailing to enter the river. In 1947, the accident resulted in no legal or other complaints against the company. The break was promptly repaired and the company even received a commendation for its pollution control efforts by the Colorado Fish and Game Department. By 1975 the story was different; Standard Metals was fined $25,000 for contaminating the river. This was the largest fine levied against a polluter in Colorado at that time. Active water quality monitoring of the tailing decant water became standard practice about 1977 with the advent of the National Pollution Discharge Elimination System (NPDES) permitting system. Bill, after this the road, constructed of tailing (ca. 100,000 tons) was washed into the Animas when the culvert failed.

Milling technology in the period was one of gradual improvement in efficiencies. Metal recovery was over 95% efficient by the 1940's and only incremental changes were made into the 1970's. The only major change was the abandonment in the mid-1930's, of the old oil-flotation chemistry at Shenandoah, for the more efficient xanthate flotation reagents which allowed separation of a separate zinc concentrate such as was done at Sunnyside. In 1965

Standard Metals noted in its annual report: "Tailing disposal systems were improved in line with current stream and river pollution regulations and practices." showing Colorado had ongoing regulations prior to national legislation.

During the period 1935 – 1991 an estimated 9,610,232 tons were mined and milled with all but about 200,000 tons of tailing being impounded in tailing ponds. Total production for the entire one hundred twenty-one year period 1871-1991 is estimated at 17,400,000 tons with an estimated 7,500,000 tons discharged into the watershed.

C. ENVIRONMENTAL ASPECTS

In many ways mining's impact on the environment lessened over the years as attitudes and regulations changed, and practices improved. Also the number of operating mines and prospects markedly decreased after 1953 as mining economics became less favorable. Underground practices continued much as in the past but longer, lower elevation tunnels increased mine drainage discharges. Annual production remained about the same, averaging around 250,000 tons. Unlike other mining areas where mines continued to grow in size, even Silverton's largest mines could not sustain production much above 700 tons per day for any long period of time. Smaller mines dwindled in number except during the war years and no single small mine exceeded 100 tons per day of new production.

The war years (1942-1952) resulted in significant road building, re-mining of dumps, and re-opening of old mines. Little regard was made to the condition of the surface after such war inspired activities and most old mills were burned for their scrap metal. Some of these sites resembled a war zone themselves after wartime savaging of ore and metal. Underground workings of the larger mines expanded to tens of thousands linear feet with many multiple levels continuing impacts on groundwater hydrology. Potential for metal laden drainage into the streams increased. Few new surface dumps were created during the period since all mineralized material was milled. The several new access tunnels built did generate large dumps, but contained mostly un-mineralized "country" rock with only limited potential for environmental impact. Reclamation laws since 1976 have tended to minimized surface impacts.

Key legal actions in the 1930's finally pushed the industry to find solutions to the tailings discharge problem. In March 1935, the Colorado Supreme Court upheld a lower court ruling against the Chain-O-Mines Company in Central City and ordered it to cease tailings discharges. (Smith 1987) Legal action was never taken against Shenandoah-Dives, who instead cooperated with downstream farmers and ditch companies to find a solution it could afford. Tailings ponds were begun in July 1935 and by June 1936 the majority of tailings were retained. By August 1937 the system achieved complete retention. As Manager Chase wrote in a 1938 article about the work: "Decanted water is, for the most part above reproach as to clarity. The Animas is reported a first-class fishing stream." Still, noting new grass growing on the sand wall he wrote, "we may yet demonstrate to the farmers that they are deprived of good soil building material." Charles Chase was ahead of his time but still believed the tailings themselves benign or even beneficial. It would take future scientific research to dispel this opinion held so long by mine operators. (Smith 1987)

When the Sunnyside reopened in 1937 tailing ponds dams built with mechanical excavators were used to withhold the tailing in the broad Animas river floodplain south of Eureka. After the mine was abandoned and the Eureka mill scrapped in 1949, these dams were breached and most of the 1937-38 tailing re-entered the river.

Other than the occasional accident or error, decant water quality could vary for a number of factors. Wind and thunderstorms would sometimes stir up the shallow water in the pond, allowing slimes into the discharge. Close attention by the operators was needed to keep the decanted water clean. Still occasional complaints were registered with the state and against Shenandoah and other 1940's operators when conditions downstream deteriorated.

Chemical or metallic constituents of decant water were not regulated until the late 1970's. Beginning in 1937, small amounts of cyanide (under 10 ppm) were used in the mill water to depress iron in the flotation process. (S-DM Co. *Reports*) Existing 1940's correspondence from the state Fish and Game department to Shenandoah never mentions any concern over chemical contents. Presumably levels used did not cause any obvious problems to fish. Small amounts of cyanide were used until the end of milling in 1991, though in reduced amounts as discharge regulations became more stringent. Even at the time of the Mayflower Mill's closure, the bio-toxicity of various mill reagents was not well understood. Xanthate concentrations in mill discharges were never regulated by state or federal agencies during the mill's operating life.

One dramatic event did adversely affect the Animas River for a short time in 1978. Standard Metals was mining a good gold vein under Lake Emma, located at 12,000 foot elevation in Sunnyside Basin. Unknown to the miners, thousands of years before, glaciers had gouged a crack along the weak vein rock and it was filled with permafrost. Heat from the mine melted the frozen mud and the lake crashed through the mine on Sunday, June 4th, 1978 the only day no miners worked underground. An estimated 6,000,000 gallons of water gushed out the American Tunnel into Cement Creek, and Terry Tunnel into Eureka Creek. The river turned black from the glacial muds and sediments well past Farmington, New Mexico. The towns of Durango and Aztec had to shut off water pumping plants to prevent the black water from entering municipal water systems.
Add paragraph on the construction of the water treatment plant, first at the American tunnel and later, at the Terry portal. To meet discharge permits requirements.
At the time of the disaster, most downstream users and the press thought Lake Emma was full of mercury and metal laden tailings from an early Sunnyside mill. This was incorrect because the first mills were built down stream of the lake. In fact water from the lake was piped to a water wheel to power the stamps of the mill downstream. (Bird 1986) The river was fouled with natural glacial sediments, diesel fuel oil from mine equipment, and a small amount of fine sulfide ore particles from the mine and natural erosion in the basin. Large ore chunks from the collapsed stope never made it past the portal. No adverse environmental affects were noted and the company was not fined by any state or federal agency. The accident was determined to be an "act of God" in a federal court action brought on by the mine's insurance company. Standard Metals won the suit and the insurance company paid out $9,000,000 in claims. Water drainage was significantly altered in Sunnyside Basin but was largely mitigated through major reclamation efforts by later mine owner Echo Bay who ironically was not originally responsible for the problem.

Water drainage from long tunnels such as the American Tunnel became targets of regulatory and environmental scrutiny when "point source" discharges became regulated in the 1970's. Echo Bay is now working to eliminate the drainage by installing hydraulic seals in the tunnels. It is hoped this will prove a permanent solution to mining's one hundred year battle with water and drainage problems, both operational and regulatory.

CONCLUSIONS

1. Prior to the 1930's mining waste deposited on surface and underground was often considerably mineralized with zinc and other sulfide minerals, which were unmarketable with the technology in use at the time. Most surface mine dumps in San Juan County probably date from these early periods.

2. After 1890, mine workings continually expanded in length, depth, and vertical extent, locally impacting groundwater hydrology and resulted in increasing mine water drainage into the watershed. The environmental significance of these discharges was not recognized until the early 1970's.

3. Prior to 1921, stamp mill tailings deposited in the river contained zinc and other unrecoverable sulfide minerals. Although they impacted downstream water quality, no organized legal action was taken against Silverton mining companies although complaints were made. The degree of downstream degradation may have been somewhat lessened due to the coarseness of the stamp mill tailing.

4. After 1918 and prior to 1936, fine flotation mill tailings discharged into the river caused significant water quality problems due to sedimentation far downstream, though they contained considerably less concentraate zinc and other sulfide minerals than stamp mill tailings. Complaints about the practice increased over time and organized legal action was taken against the largest operation in 1930.

5. During the period 1890 to 1936 an estimated 7,500,000 tons of mill tailings were discharged into the Animas River and its tributaries in the upper river watershed.

6. After 1936 mill tailings were not discharged into the river, except by accident or error. Occasional

complaints were made by downstream water users but in general mine operators worked in good faith to keep the river clear as possible with the technology in use at the time (i.e. tailings and mill process water impoundment and decant).

7. Government policies supported mining activities both directly and indirectly into the 1950's, particularly during the period 1877-1893, the First and Second World Wars, and the Korean War.

8. Possibly several hundred thousand tons of mine dumps were removed from mine sites and re-processed during times of high metal prices, particularly during World War II and the Korean War.

SOURCES & REFERENCES

Put in Alphabetical order

Colorado Bureau of Mines, *Report of the State Bureau of Mines for 1897* (Denver, CO., 1898)
Ransome, Frederic L., *Economic Geology of the Silverton Quadrangle, Colorado* (USGS, Washington, D.C., 1901)
Henderson, C. W., *Mining in Colorado – History, Development & Production* (USGS, Washington, D.C., 1926)
Taggart, Arthur F., *Handbook of Ore Dressing* (J. Wiley & Sons, New York, NY, 1927)
Rickard, T.A., *A History of American Mining* (McGraw-Hill, New York, NY, 1932)
Root, A.P., *Field Notes – Animas River Water Samples* (Durango, CO. 1930)
US Smelting & Refining, *Correspondence with Root & Norton Assayers & Chemists* (Durango, CO 1930-1932)
Chase, C.A., & Kentro, D.M., *Tailings Disposal Practice at Shenandoah-Dives* (Mining Con. Journal, March 1938)
----------------------, *The Shenandoah-Dives Mine* (Mining World Magazine, June 1942)
Chase, C.A., *Shenandoah-Dives at its Quarter Century* (1951 Mining Yearbook, Denver, CO. 1952)
Shenandoah-Dives Mining Company, *Annual Reports* (Kansas City, MO. 1930-1952)
US Bureau of Mines, *DMEA Project 2991Reports-Shenandoah-Dives Mining Co.* (Denver, CO 1955-1963)
Burbank, W.S. & Luedke, R.G., *Geology & Ore Deposits of the Eureka District et al.* (USGS, Wash. DC, 1969)
Standard Metals Corporation, *Annual Reports* (New York, NY. 1960, and various years 1959-1978)
Brown, Robert L., *An Empire of Silver* (Sundance Books, Denver, CO. 1984)
Bird, Allan G., *Silverton Gold* (Lakewood, CO. 1986)
Echo Bay Mines, *Annual Reports* (Denver, CO 1986, 1987)
Niebur, Jay E., *Arthur Redman Wilfley - Miner, Inventor, & Entrepreneur* (Colo. Hist. Soc., Denver, CO., c 1986)
Smith, Duane A., *Mining America - The Industry & the Environment* (Univ. of Kansas, Lawrence, KS. 1987)

NOTES ON THE CHART OF TOTAL ESTIMATED MINE PRODUCTION

Statistics on total annual mine production were complied by the now defunct U.S. Bureau of Mines and other agencies after 1901. The author is unaware of any comprehensive published source for this data. Therefore, the total tonnage estimates used in the report and chart of Estimated Tonnage 1871-1991 are based on a variety of sources, and estimates as follows: 1. . Out of the total estimated production of 17,400,000 tons 14,000,000 tons is documented with an additional 2,000,000 tons based on high probability estimates for gaps in data on known productive mines. Only 1.4 million tons are based on lower probability estimates.

1. Data from 1871-1900 is recorded in Charles Henderson's *Mining in Colorado* (1926) but as annual dollar value of ores produced, not tons. Tonnage through 1893 is estimated by assuming an average value per ton and calculating accordingly. These tonnages are therefore the least accurate. For 1894 -1900 actual average ore values per ton for 1901are used to back calculate the tonnage from the dollar figures.

2. From 1901-1923 tonnage cited is from Henderson, 1926.

3. Tonnage for 1924 -1926 is estimated from 1927 production quoted in Burbank & Luedke 1969, and adjusted by mill production rates as quoted in Bird 1986, and Taggart 1927; this being mostly Sunnyside production.

4. Total actual production for the period 1928-1949 inclusive was complied by Henderson at USBM for use in Chase's 1952 article on Shenandoah-Dives' 25th anniversary, but was not broken out as annual figures.

Annual figures for Shenandoah-Dives and Highland Mary are available from company annual reports, author's collection. Production figures for the Eureka District, including Sunnyside for 1932 – 1957 are found in Burbank & Luedke, 1969. These documented sources account for 90% of the 5,268,447 tons compiled by Henderson for the period. The undocumented balance of about 500,000 tons was allocated on an annual basis of known mill capacity for the Pride of the West mill after 1940 and custom capacity at Shenandoah. The total for the 22 year period is accurate but individual years may be imprecise.

5. Tonnage for 1950-1957 was based on a similar method using actual Shenandoah-Dives and Burbank & Luedke data with estimates added for other mostly small operations (i.e. Gary Owen Mine).

6. For the period 1958 – 1978 Sunnyside, Marcy-Shenandoah, and Silver Lake production, plus custom ore, is based on annual reports of Standard Metals Corporation, author's collection with estimates for Dixilyn (20,000 tons from Oceola, Ransom, and Highland Mary dump) and the Pride Mill (20,000 tons from Silver Wing 1963-1965) added.

7. After 1978, Sunnyside production is based on data in annual reports for 1984 -1987. Other years were estimated based on known mill production rates. Again estimates of 20,000 tons milled by three operators at the Pride Mill at Howardsville 1979-1981 were added.

AUTHOR INFORMATION

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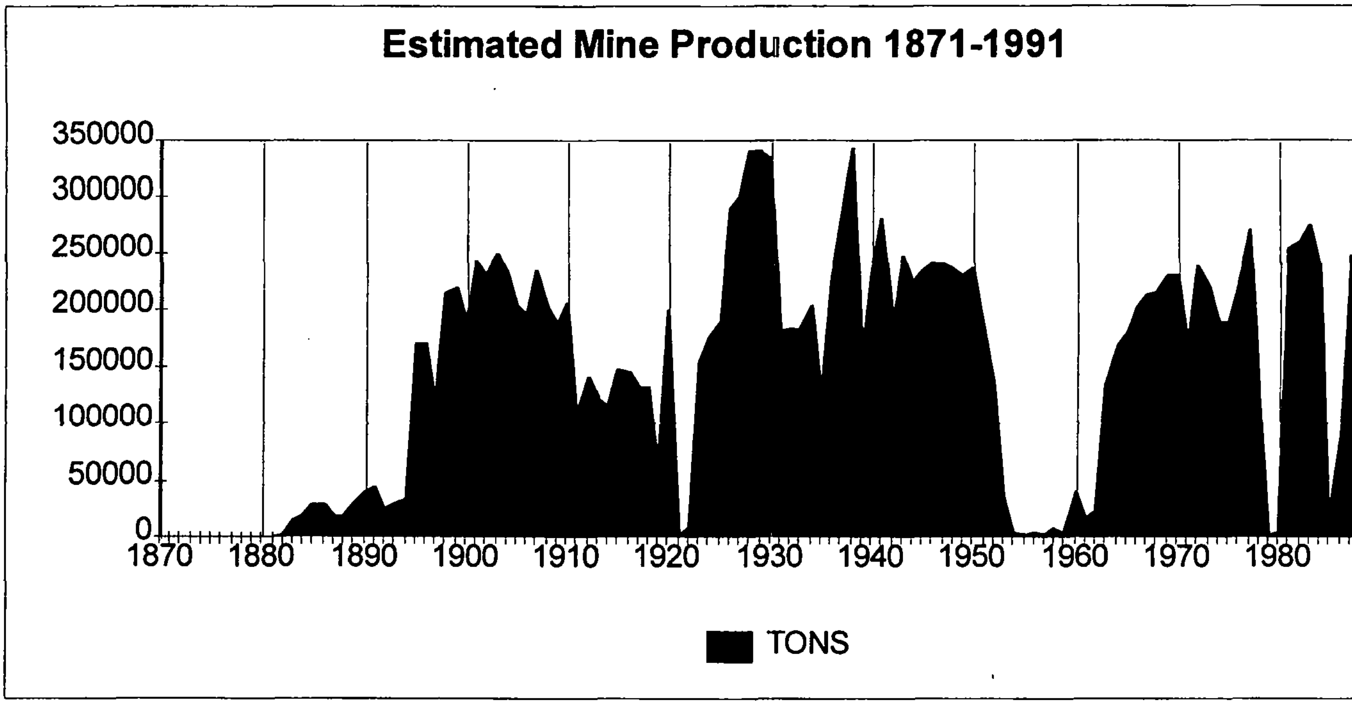

Estimated Mine Production 1871-1991
350000
300000
250000
200000
150000
100000
50000
0
1870
1880
1890
1900
1910
1920
1930
1940
1950
1960
1970
1980
TONS

Chapter III - Addressing Water Quality

DRAFT 5/10/00

Sorting out issues of fairness, practicality, and cost-effectiveness in trying to improve water quality in the Upper Animas Basin (Basin), is a daunting task. It is especially difficult given our current framework of environmental law and regulation, and current level of resources. Regulatory practices used in other places to manage other types of water quality problems may not work well here. Why?

Recognizing these difficulties, the Colorado Water Quality Control Division (WQCD) asked a non-profit, the Colorado Center for Environmental Management (CCEM) to facilitate meetings of potentially interested parties – stakeholders. Meetings began in early 1994 in Silverton and were geared towards finding consensus regarding water quality classifications and standards for an upcoming Water Quality Control Commission (WQCC) rulemaking hearing held in Silverton in September. The only consensus reached was to work together to improve water quality in the Animas River.

Animas River Stakeholders Group

Since these early meetings, an *ad hoc* group of individuals representing a wide variety of interests has been meeting almost monthly to address water quality issues in the Basin. The Animas River Stakeholders Group (ARSG) has no formal organization. Any interested party can come to meetings and participate as a stakeholder. Decisions are made by consensus, or at least acquiescence by some members. The group hired a coordinator in 1995. It built a relationship with a non-profit in Durango to manage grants - the San Juan Resource Conservation and Development Corp. (SJRCD), an offshoot of the Natural Resource Conservation Service in the Department of Agriculture. A list of participants is shown in Figure 3-1.

Figure 3-1
Participants in the Animas River Stakeholders' Group

Alpine Environmental Services	
Colorado Center for Environmental Management	Root and Norton Assayers
Colorado Dept. of Public Health & Environment	Private Citizens
Colorado Division of Minerals and Geology	St. Paul Lodge
Colorado Division of Wildlife	San Juan County Commissioners
Colorado Geological Survey	San Juan County Historical Society
Colorado River Watch (local schools)	Silver Wing Co., Inc.
Durango, City of	Silverton, Town of
Durango and Silverton Narrow Gauge Railroad	Southern Ute Tribe
Echo Bay Mines Ltd.	Southwestern Colorado Water Conservation District
Fort Lewis College	Sunnyside Gold Corp.
Friends of the Animas River	TUSCO
Gold King Mines	U.S. Army Corps of Engineers
Little Nation Mining	U.S. Bureau of Land Management
Mineral Policy Center	U.S. Bureau of Reclamation
Mining Remedial Recovery Co.	U.S. Environmental Protection Agency
OSIRIS Gold	U.S. Forest Service

The main impetus for ARSG's continued existence is first, a desire to have some local control over decisions affecting the Upper Animas Basin, and second, a realization that organizations must pool their resources to effectively characterize and address the very complex water quality issues in the watershed. Participants understood early in the process that nobody has a complete understanding of where the sources of metal loading are or what can be done about them. It is a learning experience for everyone.

Abandoned Mined Lands Initiative

Approximately 85% of the land in the Upper Animas Basin is under public ownership. A large number of abandoned mines are located on U.S. Forest Service (FS) or U.S Bureau of Land Management (BLM) property. There are thousands of abandoned sites on public lands throughout the West. To better understand how to handle problems these sites may create, the Department of Interior began an Abandoned Mined Lands Initiative (AML) in 1997 to study two pilot areas – one is the Boulder Creek drainage in Montana and the other is the Upper Animas Basin. (Buxton, date not page p.9)

The Initiative is an interdisciplinary, watershed based study designed to characterize metal loading sources and their effects on aquatic biota, discover methods to reduce those loads, and implement reclamation projects. The work combines a wide range of scientific disciplines and expertise from a number of government agencies. The objectives of the Initiative are to:

- "Determine the physical, chemical, and biological processes that control the environmental effects of abandoned mine lands,
- Define the extent of contamination and of adverse effects on the aquatic ecosystem,
- Define pre-mining background conditions to establish realistic targets for cleanup activities,
- Identify sites that most substantially affect watershed quality and public safety, enabling resources to be invested where they will provide the greatest good,
- Develop scientific information and methods to characterize contamination, evaluate human and environmental health risk, and design and monitor remediation,
- Transfer these methods and information to federal land management agencies and industry to enable efficient clean up of abandoned mine lands nationwide." (Buxton, datep.9)

A number of studies from the AML Program have been used in this UAA for characterizing the watershed. Reclamation work has begun on several public land sites. So far, nearly $5.5 million has been spent in the Basin on what?. (Robinson, unpublished data sheets) Most of the work under the Initiative has been completed and reports are being generated.

Watershed Characterization

Much of the work done by ARSG and done under the AML program has been characterizing the watershed. This includes identifying and understanding the sources of metal loading and how those loads are transported down the watershed, identifying factors that may limit aquatic life such as metal loading and habitat, and analyzing sediment data for metal concentrations pre- and post-mining. The following paragraphs briefly summarize some of the data that have been collected. Later chapters describe the results of analyses of the data. Many of the actual studies are included in the Appendices.

The shear size of the Upper Animas Basin and multitude of loading sources, whose contributions change with the seasons, has made watershed characterization a monumental task. The Basin includes three major drainages: Mineral Creek, Cement Creek, and the Animas River. It covers 146 square miles - 93,000 acres (Leib, 2000) and has over 1,500 patented mine sites. U.S. BLM has inventoried another 300 unpatented sites on its lands(Hite, 1995) Add FS inventory too. A large amount of loading comes from non-identifiable sources.

Water Quality Data

Some of the first investigations into water quality on the Animas River occurred in the 1960's. More water quality work and a couple of biological studies were completed in the 1970's. These reports are summarized in a report by Allen Medine (Medine, 1990). A use attainability analysis was conducted on the Upper Animas River and Cement Creek in 1984 by Western Aquatics for the Standard Metals Corp., owner at the time of the Sunnyside workings (Western Aquatics, 1985). All of these studies identified heavy metal loading as the main inhibiting factor to aquatic life.

It is difficult to compare much of chemical and biological data from these earlier investigations to studies conducted in the 1990's because the parameters measured, and field and analytic techniques used, were frequently different than those measured and used today. However, it does appear that there have been definite improvements in water quality and biologic health of the Animas River. Some of the same chemical parameters have improved and more fish have been found in the Basin.

From 1991 to 1993, WQCD collected substantial amounts of chemical and biological data for the 1994 rulemaking hearing discussed in Chapter I (WQCD, 1994). The information identified the main, general source areas for heavy metals. These studies have been greatly expanded upon by ARSG and the AML program throughout the nineties.

Four gaging stations have been set up and maintained for the past seven years in the Basin. Two stations are located at the mouths of Mineral and Cement Creeks as they flow into the Animas. The other two are located on the Animas; one just above the confluence with Cement Creek and the other below the confluences with Mineral and Cement Creeks (below Silverton). This last site is referred to as A-72. Water quality data is generally collected monthly at these sites by a variety of different entities.

High flow and low flow synoptic (meaning same day) samplings have been done on all three major drainages – eight synoptic samplings altogether. Each synoptic sampling on Mineral and Cement Creeks was run in one day. The Upper Animas River was broken into two parts, above and below the old townsite of Eureka.

These sampling events involve taking flow measurements and water quality samples at fifty to eighty different locations along each main stem, bracketing incoming tributaries. All draining adits in each sampling area were sampled the next day. These efforts, involving personal from many agencies and a number of volunteers, provide the basis for determining metal loadings from different areas.

In addition to the synoptic samplings, eight tracer experiments have been run at various locations. Tracer experiments were run over the entire length of Mineral and Cement Creeks and significant parts of the Upper Animas River during low flow. Other tracer experiments were done on particular sub-segments in the Basin. Should you introduce purpose here before description below.?

For a tracer experiment, a consistent salt concentration is injected into a stream. Water samples are taken at intervals, perhaps a hundred yards apart, over a stream segment to be tested. By measuring the dilution of the salt concentration at each interval, the in-flow of water between intervals can be determined. If the flow of all surface water entering between sampling sites is measured, the groundwater inflow can be calculated. Water samples are also analyzed for metal concentrations. Therefore, sources of metals, including groundwater sources, can be precisely identified. (For a much greater description of the process, see Kimball *et al*, 1999.)

Very intense water quality sampling was done in three smaller, sub-basins in the area. Every seep, spring and draining adit that could be identified was sampled and flow measured. By comparing all of these loads to the load found at the mouth of the drainage, the relative contributions of natural versus human-induced metal loading could be estimated (Wright, 1997).

Different companies and agencies also did substantial sampling around potential remediation sites. Sites that have been or are undergoing remediation are listed in Table 3-1 below. Overall, a total of about 4,000 to 5,000 water quality samples have been taken.

Locating and Sampling Waste Rock and Tailings Piles

As part of the AML Initiative, surveys locating sites of past mining activity on public lands have been completed. Many sites lie on a mixture of public and private land. I don't think so--these were BLM & FS internal funds before AML. This should be mentioned above as its more than waste.

A number of material samples were collected from each of approximately 250 waste rock piles (dumps) and tailings piles in the basin. These samples were tested for acid generation potential and heavy metal concentrations. ARSG has collected composite surface samples of approximately 160 mine waste piles and tailings. Samples were uniformally subjected to a water leach test to determine their leaching potentials for acidity and dissolved metals.

Sediments

Sediment samples were collected from the river bottom along the entire 110 mile length of the Animas River to help determine the sources, fate, and transport of metals . (Church *et al.*, 1997). Sediments from historic river channels were also collected at strategic locations to analyze the changes in metal concentrations from pre- to post-mining periods. (Church *et al.*, 2000).

Biological Data

Macroinvertebrate data has been collected three times at approximately fifty sites throughout the length of the river. This information has been analyzed to provide a benchmark condition which can be used to compare to the results of furture remediation efforts. In addition, sampling methods, sites, analytic methods, and metrics for future evaluations have been established. Species lists, possible indicator species, and sensitive species for stream segments are another product of this work. The initial impact of improvements in water quality will most likely show up in macroinvertebrate counts downstream.

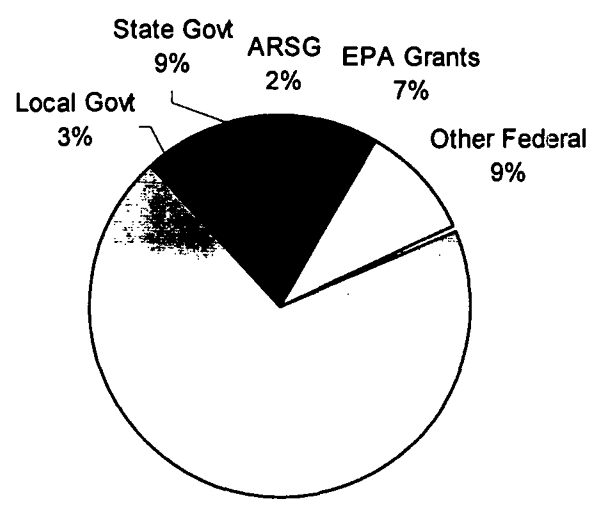
The Colorado Division of Wildlife (DOW) and others have done several electro-shocking fish studies thorughout the basin. in the Animas River both around Durango and in the Basin. Surveys have shown improvement in fisheries between 1992 and 1998.

Other biological studies have examined factors that might limit aquatic life including: toxic thresholds of three species of trout and 2 macroinvertebrates for several metals, , I don't think we're going to get this afterall, toxicity of water in the pore space in the substrate, the biological impactt of smothering of the substrate with iron and aluminum colloidal deposits (or precipitates) , and physical habitat attributes and limitations. .

Geology and Initial Remediation Plans

The Colorado Division of Minerals and Geology and U.S. Geological Survey have mapped and described many of the geologic features in the Basin that can be sources of metal loading and/or buffering.. The Division also devised preliminary ?initial remediation plans for most of the inactive and abandoned mine sites throughout the Basin based upon results of source characterization and preliminary feasibility analyses. (Herron *et al*, 1997, 1998, 1999)

Figure 3-1 - Funding for Characterization and Coordination



Overall a prodigious amount of effort have gone into characterizing the Upper Basin. So far over $7.2 million has been spent. Some work is still in progress. Figure 3-1 shows funding sources for characterization and coordination in the Basin over the past ten years.

Source: Rob Robinson, U.S. BLM, Denver, CO, unpublished spreadsheet on expenditures in the Upper Animas Basin plus personal communication with other stakeholders.

Yet with all of these resources committed to characterization, even more resources have gone into actual remediation.

Remediation

A number of sites have been remediated in the Upper Animas Basin. Most of the work has been done by Sunnyside Gold Corporation (SGC), owner of the largest, most productive mine in the Basin. SGC entered into a voluntary Consent Decree agreement with the Water Quality Control Division (WQCD) effective May 8, 1996. This agreement provides a settlement to a dispute over seeps and springs that may result from bulkhead closures of the Sunnyside Mine to eliminate discharges through the American Tunnel and Terry Tunnel.

The agreement provides for SGC to implement permitted mine remediation projects in the Basin to offset potential impacts to water quality from seeps and springs that may result from the mine closure. Success of the mitigation program will be measured at a reference point (A-72) which is the USGS gaging station on the Animas River below Silverton. In order for the agreement to be successfully completed, dissolved zinc concentrations at A-72 must not increase when statistically compared to a reference data set over a time period specified in the Decree.

Upon successful agreement completion, the NPDES permits for the American Tunnel and Terry Tunnel discharges will be terminated by WQCD and SGC will have no future liability in the Basin for any seeps and springs that result from bulkheading the tunnels to eliminate discharges. This action will allow final Sunnyside Mine reclamation. So far, SGC has spent over $10 million on reclamation in the Basin and does not plan to spend much more under the Decree.

Other reclamation projects in the Basin have been partially funded by 319 non-point source funds (or the 319 Non Point Source Program). Some project sponsors have been small private mining companies and property owners. Others have been sponsored by ARSG. In addition, remediation projects on public lands have been funded through the AML Inititative.

Funding sources for remediation are broken up into two charts, Figures 3-2 and 3-3. The first displays the percentages of funding for all remediation efforts. The vast majority of the funding comes from Sunnyside Gold Corp. The amount of funding spent or currently committed to remediation totals over $11.5 million – about $11 million has been spent.

The second chart is a subset of the first and shows funding for voluntary remediation – that which was not tied directly to a regulatory settlement or action. For some of these projects, funding is committed, but work has not been done. All of EPA's funding is in the form of 319 grants which are awarded and managed by the WQCD. ARSG's funding consists mostly of in-kind services and volunteered time. The total funding represented by this chart amounts to $1.7 million.

Table 3-1, below the charts, summaries completed or on-going remediation efforts in the Basin. It does not include some projects that are funded, but have not yet begun. The Figure 3-4 shows the locations of projects listed in Table 3-1.

Peter, I have had T. Strain develop the specific base maps for various sections of the UAA. Will send those to you so you can pencil in what you need. Then he can add the overlay and print the map.

Figure 3-2 - Funding for Remediation

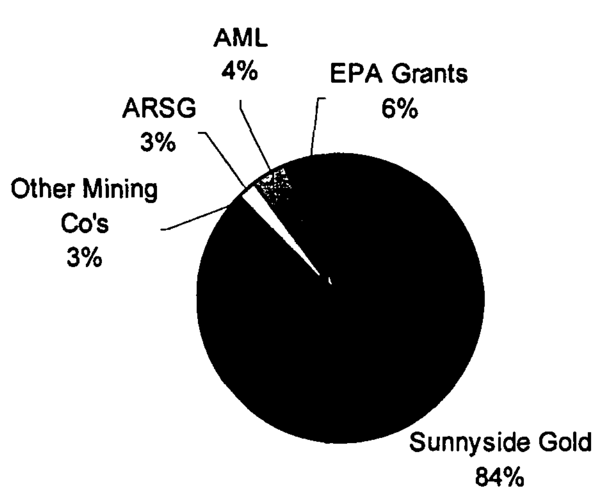
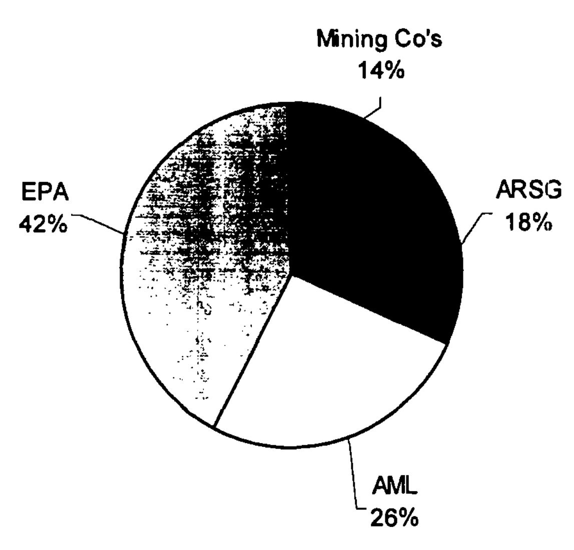


Figure 3-3 - Funding for Volunteer Remediation



Source: Rob Robson, U.S. BLM, Denver, CO, unpublished spreadsheet on expenditures in the Upper Animas Basin plus personal communication with other stakeholders.

(Insert Table 3-1 – Summary of Reclamation Projects)

(Insert Figure 3-4 – Locations of Reclamation Projects)

References:

Buxton, Herbert T. "A Watershed Approach to Contamination of Abandoned Mined Lands: The USGS Abandoned Mined Land Initiative," *U.S. Geological Survey Toxic Substances Hydrology Program- Proceedings of the Technical Meeting, Charleston, South Carolina, March 8-12, 1999*, Water Resources Investigations Report 99-4018A.

Church, S.E., B.A. Kimball, D.L. Fey, D.A. Ferdered, T.J. Yager, and R.B. Vaughn, *Source, Transport, and Partioning of Metals between Water, Colloids, and Bed Sediments of the Animas River, Colorado*, U.S. Geological Survey Open File Report 97-151, 1997.

Church, S.E., D.L. Fey, and Robert Blair, "Pre-Mining Bed Sediment Geochemical Baseline in the Animas River," Precedings of ICARD Conference, May 2000.

Colorado Water Quality Control Division, *Exhibit 3 – Upper Animas Water Quality Classification and Standards Proposal*, July 1994, presented to the Colorado Water Quality Control Commission.

Herron, Jim, Bruce Stover, Paul Krabacher, and Dave Bucknam, *Mineral Creek Feasibility Investigations Report*, Colo. Division of Minerals and Geology, Feb. 1997.

Herron, Jim, Bruce Stover, and Paul Krabacher, Cement *Creek Reclamation Feasibility Report*, Colo. Division of Minerals and Geology, Sept. 1998.

Herron, Jim, Bruce Stover, and Paul Krabacher, R*eclamation Feasibility Report Animas River above Eureka*, Colo. Division of Minerals and Geology, Oct. 1999.

Hite, Barbara J., *Abandoned Mine Land Inventory of BLM Administered Land in Upper Animas River Watershed, Colorado*, Colorado State BLM Office, Denver, CO., Feb. 1995.

Kimball, Bryant A., Robert L. Runkel, Kenneth E. Bencala, and Katherine Walton-Day, "Use of Tracer-Injection and Synoptic-Sampling Studies to Quantify Effects of Metal Loading from Mine Drainage," *U.S. Geological Survey Toxic Substances Hydrology Program-Proceedings of the Technical Meeting, Charleston, South Carolina, March 8-12, 1999*, Water Resources Investigations Report 99-4018A.

Leib, Ken, USGS, Durango, unpublished spreadsheet describing drainage areas for different sampling points in the Upper Animas Basin, Mar. 2000.

Medine, Allen J., *Water Quality Assessment, Animas River Basin,* prepared for U.S. Environmental Protection Agency, Region VIII, Denver CO., Feb. 2, 1990.

Robinson, Rob, U.S. Bureau of Land Management, Denver office, unpublished spreadsheet describing expenditures in the Upper Animas Basin, Jan. 2000. Periodically updated.

Western Aquatics, Inc., *Use Attainability Analysis of the Upper Animas River*, prepared for Standard Metals Corporation, Silverton CO., Jan. 22, 1985.

Wright, Winfield G., *Natural and Mining-Related Sources of Dissolved Minerals during Low Flow in the Upper Animas River Basin, Southwestern Colorado*, Fact Sheet FS-148-97, Oct. 1997, U.S. Geological Survey, Durango, CO.

Animas River UAA
Section II
Protecting Existing and Potential Uses

Draft 2/17/00

Use classifications and standards are designed to protect existing and potential aquatic life conditions and beneficial uses. An array of programs has been developed to insure the use classifications and standards are met. Some programs are regulatory, requiring permits. Others are voluntary. Some regulatory programs are enforced more vigorously than others are. This section describes how those programs apply to the Upper Animas Basin.

Sources of contamination to water resources fall into two categories, point sources and non-point sources. Point sources are locations where water has been collected and discharged at a particular point, generally through a pipe or a ditch. (CWA § 502 (14)) Discharges of pollutants in a more dispersed fashion are considered non-point sources. The importance of the distinction is that point sources are regulated through discharge permit requirements and non-point sources are not, although non-point sources may be regulated indirectly through other permit requirements (*i.e.* regulations on the application of pesticides.).

Point Source Permits

Point sources include discharges from municipal wastewater plants and industrial process facilities. Should use Process permit and Stormwater permit in wording perhaps to be consistant with Process permit mentioned in the next paragraph. Permits for these discharges require treatment of contaminants and monitoring demonstrating compliance with permit parameters. Stormwater runoff from a variety of municipal, industrial, and construction areas (usually larger) is also considered a point source that needs permitting. Most of these permits require "Best Management Practices" (BMP's) to reduce problems caused by runoff. Both the state and EPA have developed comprehensive descriptions of BMP's for mining activities. (See Colorado's Non-Point Source Management Handbook, Chap. 5 and 60 Fed. Reg. 50888) Stormwater permits generally do not require strict numeric effluent limits and monitoring procedures applied to other point source permits. Permits for both stormwater and non-stormwater point sources are known as National Pollutant Discharge Elimination System (NPDES) permits. In Colorado, they are known as Colorado Discharge Permit System (CDPS) permits because the state has been delegated to administer the Federal Clean Water Act.

Inactive and abandoned mine sites are required to have stormwater permits if stormwater comes "into contact, or is contaminated by, any overburden, raw material, intermediate product, finished product, by product, or waste product located on the site of the operation." (60 Fed. Reg. 51155) This includes runoff from roads or dams/dikes constructed of waste rock or tailings. These permits do not cover runoff that is mixed with other sources of contaminants such as mine (adits and portals are a subclass of a mine entrance) drainage or contaminated springs or seeps on site. According to the U.S. Environment Protection Agency (EPA), these other sources need **a process water NPDES permit**. Some members of the mining industry disagree with this opinion. (*Colorado Mining Water Quality Task Force Report*, July 1997)
Be consistant--Discuss Process permits, then stormwater.

To terminate a stormwater permit, BMP's must be implemented to minimize? Reduce? Eleminate? the potential sources of contamination listed above, and erosion is controlled. (See CDPS General Permit for Stormwater Discharges Associated with Mining) Process water NPDES permits can only be terminated when no potential contamination will be emitted from these sources. It can be very difficult to meet this condition, especially if the source is a draining mine .

Enforcement

The vast majority of inactive and abandoned mine sites in Colorado do not have the requisite water quality control permits. It is EPA's opinion that mine discharges should be treated as point sources There are thousands of sites around the state, and because of limited resources, the state has made permitting these sites a low priority. For example, while there may be 2,000 mine sites and 400 draining adits in the Upper Animas Basin, there are only two process water NPDES permits (including the Silverton wastewater treatment plant) and only XX mining-related stormwater permits. Generally, permitting is only enforced when a property owner plans to take some physical action on his or her property, particularily to renew mining activities. Depending on resources and political climate, the level of enforcement may change in the future.

Not only are current property owners liable for these NPDES permits, but past owners, operators, or anyone else who has worked on a site can also potentially be held liable for discharge of pollutants (not for the permit though, I don't think.. This broad reach of potential liability is a significant barrier to "Good Samaritan" actions. A "Good Samaritan" can be government agencies, private companies, or volunteer groups. All of these parties may want to remediate or partially remediate an inactive or abandoned mine site that they do not own. However, someone has responsibility for the appropriate permits until those permits can be terminated. Most groups acting as "Good Samaritans" do not want this responsibility.

A number of remediation projects around the state have been put on hold because of this liability issue. There are currently efforts to push a "Good Samaritan" provision through Congress to limit liability for third-parties working on others' property. Depending on how it is written, such a provision could have a substantialoops ok beneficial impact on volunteer remediation efforts in the Upper Animas Basin.

Non-Point Source Programs

Pollution sources that do not fall under the point source category are considered non-point sources. They are generally diffuse discharges that are more difficult to manage. Programs designed to address these sources are usually voluntary. They consist of information, education, and funding. At the state level, these programs are run through the Water Quality Control Division, Division of Minerals and Geology, and Hazardous Waste Division. All of these agencies have extensive experience and expertise in mining-related water quality issues.

Much of the government funding for remediation on inactive and abandoned mine sites has come through EPA 319 non-point source grants administered by the state. These grants are authorized by section 319 of the CWA and are used specifically to address non-point source pollution. In recent years, a number of these grants have gone to the Upper Animas Basin. Some people are concerned that this funding may not be available for mine site remediation, because EPA has had an increasing tendency to classify mine sites as point sources.

In addition to the 319 funds, several state and federal agencies have funded remediation when the efforts fell within the missions of these agencies. This is discussed further in the next section.

CERCLA

Mine property owners in the Animas Basin potentially could be required to remediate their sites under the provisions of the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA, 42 U.S.C. §§ 9601) This legislation is best known by one part referred to as "Superfund." The Colorado Mining Water Quality Task Force gives a good summary of how this legislation could affect inactive and abandoned mine properties (Report and Recommendations Regarding Water Quality Impacts from Abandoned or Inactive Mined Lands, July 1997, p. 7.):

> CERCLA permits EPA and others to undertake and ensure the cleanup of hazardous substance releases posing threats to public health or the environment. "Hazardous substances" include toxic heavy metals. CERCLA permits any person? to recover "response costs" ... from potentially responsible parties (PRP's). These PRP's may include: the current or past owner or operator of a facility; persons who "arranged for disposal" of hazardous substances; and transporters of hazardous substances. Courts have consistently interpreted a PRP's liability under CERCLA as strict, and joint and several. In addition, CERCLA provides only limited statutory defenses to liability.
>
> Given CERCLA's broad scope, it presents significant remedial and liability implications for PRP's at mining sites. For example, CERCLA liability can be imposed retroactively, and therefore, historic activities undertaken by a mine owner or operator at some time in the past, and although legal at the time, may give rise to CERCLA liability. Also, CERCLA provides little relief to entities who may initiate a voluntary clean-up at an inactive or abandoned mine where, for example, a release of hazardous substances occurs during remediation or if a residual release remains after remediation is completed.

Federal regulatory agencies (EPA, Forest Service, Bureau of Land Management) have some discretion in applying CERCLA. For example, these agencies do not necessarily have to pursue cost recovery from PRP's if the PRP's have few assets. In some cases, EPA may enter into a "covenant-not-to-sue" with a potential buyer of a site of? past contamination. In return, EPA may expect the buyer to remediate a site or reduce the potential risk of a site to the public. (Mining Task Force Report, p. 13) EPA's Regional Director has repeatedly said that EPA will not pursue CERCLA liabilities in the Animas watershed as long as progress is being made toward improving water quality. In addition, the State of Colorado and EPA have entered into a Memorandum of Understanding where the state receives protection from CERCLA liability "when engaged in the clean-up of an abandoned or inactive mine pursuant to the Clean Water Act section 319 nonpoint source program." (Mining Task Force Report, p. 13). Unfortunately there is not an agreement that would limit the states liability exposure if they chose to remediate a draining mine.

Landowner Perceptions

Because of the low level of permit enforcement, many property owners maintain a low profile, not wanting to attract attention. These owners are unclear as to what actions they might need to take and how much it might cost to meet their liabilities. Stormwater permits have fairly minimal requirements and yearly maintenance costs are minimal, are inexpensive to maintain, but those requirements may change in the future. Terminating such a permit may not be easy. Process water permits - which generally require water treatment - are much more costly, especially in remote areas, and very difficult to terminate.

Other owners wish to do something with their properties and are working to reduce their liabilities. They may want to sell, redevelop or mine their land. Some of these owners feel that their sites may contribute substantial metal loads and want to reduce their liability now in a more voluntary fashion under the current regulatory climate. If they are forced into obtaining permits or remediating a site through a regulatory action, they may have less leverage and flexibility in working with the regulatory agency.???

The owners of many abandoned or inactive sites are government agencies. The U.S. Forest Service and Bureau of Land Management own a number of abandoned and inactive sites in the basin. Some of these mines impact other types of public uses, so they are working to remediate these sites. Nevertheless, using their CERCLA authority, these agencies require a search for PRP's for past operatiors, possibly resulting in full or partial cost recovery. Some proponents of cleanups fear that forcing cost recovery, particularily from past claimants/operators who participated in an activity unregulated at the time will result in further entrenchment of private landowners/operators that otherwise may be willing cooperators. The prospect of CERCLA actions is considered to be particularly onerous by many property owners. Under CERCLA, regulatory agencies can force remediation of a site or do the remediation itself and require reimbursement by PRP's. CERCLA actions in the Basin may scare off potential buyers or investors, reducing property values. Of course, once an action is complete, the property may then be more valuable. While EPA has made good faith efforts to assure mine site owners that CERCLA actions may be applied in a more gentle, cooperative fashion than in the past, most site owners are still wary. Peter, there is a bit of a difference between EPA CERCLA action and those of LMAs. That's what I was trying to get at in the sentence or two suggested. Rewrite to clarify?

Another important landowner perception is the issue of fairness. Most mine sites in the Upper Animas Basin have not been mined in eighty to a hundred years. Most owners did not participate in mining on their sites nor did they receive direct financial benefits from the mining. In terms of environmental regulation, virtually all mining activity was done legally at the time. While a number of sites may have measurable impacts on water quality, the majority of sites contribute minimal metal loading. (See section XX below.) In addition, there is a substantial amount of natural metal loading to the system. Some people feel they may be swept up in a national regulatory framework that does not have the flexibility nor funding, to adequately address the situation in the Upper Animas Basin.

Animas River UAA
Section III
Addressing Water Quality

Sorting out issues of fairness, practicality, and cost-effectiveness in trying to improve water quality in the Upper Animas Basin, given our current framework of environmental law and regulation, and current level of resources, is a daunting task. Past regulatory practices used in other places, to control other types of water quality problems may not work well here. Thus, a number of stakeholders have been meeting and working together for six years to craft other ways to improve address water quality.

Animas River UAA
Section I - Introduction

Draft 1/19/00

The Animas River begins high in the San Juan Mountains, above Silverton, in southwest Colorado. The river flows south through Durango for almost eighty miles to the New Mexico border. It continues nearly thirty more miles, meeting the San Juan River in Farmington.

Aquatic life in much of the Upper Animas River watershed is limited or even non-existent. In areas where there is adequate flow, heavy metal loading is the main limiting factor curtailing aquatic species. Some metal loading is caused by natural processes, and some loading is the result of human activity. Other possible water quality problems have been investigated and dismissed why?as unimpairing? . (See Section IX.)

There is general agreement that the water quality in the Upper Animas River can be improved. How much improvement is possible or feasible is a difficult question which this Use Attainability Analysis (UAA) attempts to answer.

Need for a Use Attainability Analysis

One of the goals of the federal Clean Water Act (CWA) is to provide, wherever attainable, "... water quality which provides for the protection and propagation of fish, shellfish, and wildlife and provides for recreation in and on the water ..."(CWA, § 101). This is often referred to as the "fishable, swimmable standard."

State legislation closely follows the federal act by requiring the same protection for fish and wildlife and by requiring protection for "beneficial uses" such as recreation, agriculture, water supply, *etc* (Colorado Water Quality Control Act, C.R.S. 25-8-102). The state's Water Quality Control Commission (WQCC or simply Commission) and Water Quality Control Division (WQCD) in the Department of Public Health and Environment are required to implement provisions of the state Act.

Under the state's water quality protection program, use classifications are assigned to lakes or reservoirs and segments of rivers and streams. These use classifications protect existing or potential uses of that water body. Once use classifications are assigned, water quality standards are applied to protect those uses from impairment (5 CCR 1002-31.3).

The use classifications recognized by the state are: recreation (class 1 and class 2), agriculture, warm water and cold water aquatic life (class 1 and class 2), water supply, and wetlands. Class 1 recreation provides for primary contact with water – the swimmable standard. Class 2 recreation provides for secondary contact, including fishing or other riverside activity. Class 1 aquatic life, warm or cold water, refers to waters able to support a wide variety of aquatic life. Class 2 aquatic life refers to waters where there is some type of impairment to aquatic life – physical habitat, water flows or levels, or uncorrectable water quality conditions -- such that a wide variety or abundance of species is not possible (5 CCR 1002-31.13).

If streams or lakes are not assigned an aquatic life use or recreation class 1 use, an analysis is needed to determine why these uses are not attainable (5 CCR 1002-31.6(3); also see 40 CFR 131.10). A number of segments in the Upper Animas Watershed fall into this category. Therefore a Use Attainability Analysis (UAA) is needed

Triennial Reviews

Under both federal and state law, water quality standards for all surface waters of the state must be reviewed every three years. In Colorado, the review is conducted by WQCC with assistance from WQCD. This document is being prepared for the year 2000 review of use classifications and standards in southwest Colorado. The review will be conducted in August 2000. Any actual changes in the use classifications and standards will occur in rulemaking hearing scheduled for March 2001.

The UAA provides recommendations and supporting documentation for appropriate use classifications and standards for river segments of the Animas River watershed. WQCC will use this information as part of their review. In 2003, the Commission will again conduct a triennial review for this part of Colorado and may decide to make further changes based upon new information.

Current Use Classifications and Standards for the Animas River

This section summaries some important elements of Table 1 which shows current use classifications and standards for the Animas River watershed (5 CCR 1002-34.6). For a full description of all attributes of the table, refer to The Basic Standards and Methodologies for Surface Water (5 CCR 1002-31) available through WQCC directly or on its Internet site. The location of different segments is shown on Figure 1.

The first column describes each segment. There are errors in the descriptions that are discussed in the recommendations section of the UAA.

The third column lists use classifications. Those segments that have no aquatic use designation have minimal if any aquatic life. Conditions that limit aquatic life in those segments are not considered correctable, however because they greatly influence downstream conditions limiting factors reductions in these areas could be quite beneficial.

The standards listed in the columns to the right of the use classifications are designed to protect all uses listed in the classification column. Generally, aquatic life uses need the most stringent standards to prevent any impairment. Thus, aquatic life needs drive most of the standards in segments where aquatic life is a use.

The segments which garner the most concern are those with "temporary modifications," shown in the last column of the table. These are segments that have standards – called underlying standards – which are currently not being met. The temporary modifications make the standards less stringent to allow people time to comply with the underlying standards.

Note that the "temporary modifications" don't go into effect until 6/30/01. This is an anomoly in the way the Commission sets standards. The Commission took this approach because of the uncertainty involved in determining underlying standards.

In 1994, the Commission held a rulemaking in Silverton. Because of substantial disagreement between parties to the hearing, the Commission adopted WQCD's recommendations for temporary modifications and underlying standards, but delayed the implementation date for three years to allow for the collection of more information. During the delay, the standards were set equal to ambient water quality, meaning that the existing water quality was the standard (5 CCR 1002-34.23).

During the next triennial review year, 1997, the Commission was presented with information showing substantial progress in addressing water quality issues in the Upper Animas Watershed and with a request for more time to gather information and make recommendations for appropriate use classifications and standards. The Commission extended the delay of the implementation date to June 30, 2001, with the understanding that there would be no more delays (5 CCR 1002-34.37).

Water quality standards set by the Commission must be approved or disapproved by the U.S. Environmental Protection Agency (EPA) (CWA § 303(c)). EPA disapproved some of the ambient water quality standards (metals) on segments 3a, 4a, and 9b (Letter to WQCC, 8/27/98, Appendix K). EPA will only approve ambient standards when an analysis shows that water quality problems are natural, or human-caused but irreversible (40 CFR 131.10). Ambient standards were approved on segments 2, 3b, 7, and 8. EPA agreed with WQCC that analyses had shown that these segments cannot support aquatic life now or in the near future.

An analysis is needed for the disapproved segments. However, since most of the metal loading for these segments comes from upstream, the analysis must examine the loading and potential reductions in loading that may be accomplished in the upstream segments - 2, 3b, 7, and 8 – in order to protect classified uses in the lower segments.

The next four sections of the UAA provide important background information for the analysis. The physical, chemical, and biological analyses occupy sections VI through XI. Sections XII and XIII describe methods of remediation of mine sites and associated costs. The final section contains recommendations for segmentation, use classifications and standards.

DRAFT

SECTION 5: Existing Uses

Water quality classifications and standards are used to protect existing or practicably achievable uses and to establish criteria that will meet the fishable swimmable goals of the Clean Water Act. Colorado's approach is to establish use classifications and assign water quality standards, usually numeric criteria, to support those uses. Numeric criteria protect the most restrictive use. For example, standards for cadmium, copper, lead, manganese, and zinc are required for waters supporting both aquatic life and water supply uses. The aquatic life standards are more restrictive for all these metals except manganese. If these two uses are present, the aquatic life standards would be assigned for cadmium, copper, lead and zinc, but the water supply standard would be assigned for manganese. The use classifications assigned to surface waters in the upper Animas watershed are summarized in Table 5.1. The basis for assigning them are discussed in Section 5.

Table 5.1

Segment	*Description*	*Aquatic 1*	*Aquatic 2*	*Rec 1*	*Rec 2*	*Water Supply*	*Agric*
1	Weminuche Wilderness	X		X		X	X
2	Animas ab Maggie				X		X
3a	Animas ab Cement	X			X		X
3b	Animas ab Mineral				X		
4a	Animas ab Elk Creek	*	X	X			
4b	Animas ab Junction Ck	X		X		X	X
5a	Animas ab So. Ute	X		X		X	X
5b	Animas ab New Mexico	X		X		X	X
6	Upper Animas tributaries	X			X	X	X
7	Cement Creek				X		X
8	Mineral ab South Mineral				X		X
9a	South Mineral	X			X	X	X
9b	Mineral bl South Mineral	X			X		X
12a	Tributaries To 4a and 4b	X		X		X	X
15	Upper Cascade Creek		X		X	X	X

* Adopted as a goal

Aquatic Life

Aquatic life is classified as warm or cold and as class 1 or class 2. The distinction between warm and cold is whether or not the water temperature is suitable for trout (cold water fishery)

<date>

or for warm water species. Surface waters in the upper Animas basin are classified cold water. Aquatic life class 1 streams have the physical characteristics (i.e. substrate, cover, and flow conditions) to support a wide variety of cold water biota. Suitability of habitat and water quality distinguishes class 1 from class 2 streams. Streams with insufficient flow, habitat, or water quality that is either naturally impaired or irreparably impaired by anthropogenic causes may be classified aquatic life 2. One approach for determining if improved water quality in a stream could lead to more diverse forms of aquatic biota is to compare the existing aquatic life in streams impaired by mining to that of unimpaired or reference streams. The reference streams must have the same basic geology and geography region. Comparison of streams unimpacted by mines but of naturally poor quality can be compared to those with some anthropogenic impacts to get an idea of potential for improvements.

Water quality investigations of the upper Animas Basin between 1991 and 1994 found that segments 1, 3a, 4b, 5a, 5b, 6, 9a, 9b, and 12a have the capability to fully support aquatic life class 1 uses (WQCD Exhibit 3, 1994). The 1994 water quality standards hearing and EPA's letter of April 1998 concluded that segments 2, 3b, 7, and 8 do not support aquatic biota and further are irreparably incapable of supporting even limited forms of aquatic biota. These segments have no aquatic life classification. Segment 4a is presently classified aquatic life 2 owing to high concentrations of metals. The WQCC adopted class 1 as a goal for this segment if sufficient improvement in water quality can be achieved. The purpose of this UAA is to determine if the water quality classifications and standards adopted in 1995 and disapproved by the EPA in 1998 will be achieved if anthropogenic sources of metal loading are remediated.

Segment 12a includes tributaries to the Animas south of Elk Creek. They are class 1. 12a should be revised to include all tributaries to the Animas River from the confluence with Mineral Creek to Baker's Bridge which are not included in segment 15.

Segment 6 should include all tributaries to the Animas River, from Maggie Gulch to immediately above the confluence with Mineral Creek that are not specifically identified in segment 6b.

A new segment 6b should be created for Arrastra Gulch and similar tributaries that have ambient quality exceeding TVS. The segment should initially be proposed class 2 aquatic life, based on ambient quality, unless there is information to support class 1. Ambient standards should proposed (EPA will not allow ambient standards if there is possibility for improvements--there is at Silver Lake although who knows how much it will improve things--but we cannot prove it won't. A company is currently trying to permit tailings removal and leaching of Silver Lake tails. Looks more like Aquatic 2 to me. . Alternatively, these tributaries could be made a part of 3a. If class 2 aquatic is proposed perhaps CDPHE will do the analysis to determine if class 1 or class 2 is most appropriate. Recreation class 2 should be proposed for the segment. There is no evidence of current water supply or agriculture uses of the segment.

Recreation

Recreation class 1 waters are used for activities in or on the water if the ingestion of small quantities of water is likely to occur. Recreation 1 activities may include, but are not limited to waters used for swimming, rafting, kayaking, and water skiing. Class 2 waters are suitable for use on or about the water such as fishing and other streamside or lakeside activities.

Water quality standards for class 1 and class 2 recreation waters are distinguished by the standard for fecal coliform. Recreation class 2 waters have a fecal coliform standard of 2000/100ml whereas class 1 waters have a standard of 200/100ml.

Most waters in Colorado are too shallow and/or too cold to support recreational class 1 uses. The quality of many of these waters is better than what is required for class 1, (i.e. concentration of fecal coliform is much lower than the class 1 standard). In order to maintain the bacterial quality of waters in Colorado the WQCC and U. S, Environmental Protection Agency agreed to classify waters recreation 1 only when they are used for recreation in or on the water. The class 1 standard for fecal coliform, however, is adopted for class 2 waters meeting the 200/100ml standard unless existing point source discharges would incur substantial costs to meet the 200/100ml standard. Streams used for rafting and kayaking include the Animas River from near Silverton to Tacoma (segments 4a and 4b) and the Animas below Baker's Bridge (segments 4b and 5a). Segment 3b, the mainstem of the Animas River from Cement Creek to the confluence with Mineral Creek is classified recreation class 2 and has the higher fecal coliform standard because the Silverton municipal wastewater treatment plant discharges to the segment. The Purgatory WWTP discharges to segment 15 which also has the higher fecal coliform standard.

Water supply

Waters with water supply classification are suitable for potable water after receiving standard treatment, filtration and disinfection. The water supply classification is applied if the quality is suitable for that use. Bear Creek and Boulder Creek, parts of segments 9a and 6, are the sources of Silverton's municipal supply. No other public water supplier uses the Animas or its tributaries in the UAA area until the river reaches Durango, segments 4b, 5a, 5b. Segment 15, which has an aquatic life class 2 classification, has metal standards adopted for water supply.

Agriculture

The agricultural classification is used for waters that are diverted for irrigation or that may be used for watering livestock. Sheep graze the headwaters of the Animas, Mineral, and Cement Creeks in the late summer and early fall. This is the only agricultural use of water in the upper basin. The Animas River from Silverton, the beginning of segment 3b to Baker's Bridge, is not used by domestic livestock, except for occasional pack animals. Irrigation and stock watering are common uses in the lower basin. Although agricultural uses are recognized in the classifications, no standards specific to agriculture are in place for the UAA segments.

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SECTION 9: Existing Quality and Sources of Degradation

Many water quality standards for the Animas River basin changed as a result of the 1994 hearing. The changes, based on data collected between 1989 and 1994, reassessed the status of aquatic life and estimated the potential for establishing aquatic life in the Animas River and several of its tributaries. Several activities affecting water quality have occurred and new data has been collected since 1994. New data is to

quantify seasonal and annual variations in loading from identifiable mining related sources,

improve estimates of metal contributions from all other sources,

evaluate seasonal variations in water quality at the four gaging stations, and

evaluate water quality effect previously implemented remediation projects, has had on the chemistry of Mineral, Cement, and the Animas River.

These data, together with data from the earlier studies, will be used to establish water quality goals that may reasonably be achieved through restoration of disturbed sites. Alternative uses and standards that might be achieved through remediation are proposed. The UAA focuses on stream segments with aquatic life classifications and standards disapproved by EPA in their letter of September 1998 or which are contained in the state's 1998 303(d) list. The list of stream segments that do not comply with the state's 303(d) list and EPA's 1998 disapproval letter are shown in Table 9.1

In-stream water quality

Procedures for evaluating water quality and establishing standards have been adopted by the Colorado WQCC. Existing or ambient water quality is compared to Table Value Standards (TVS). The regulation defines ambient quality as the 85th percentile of representative data. If it is shown that ambient quality is better than TVS for the classified use, TVS are adopted ("The Basic Standards and Methodologies for Surface Water"). TVS for Cd, Cu, Pb, Mn, and Zn vary with water hardness. Higher metal concentrations are tolerated at higher hardness values. The practice of the WQCD has been to compare TVS using average hardness values with 85th percentile concentrations.

Ambient standards, 85th percentile, may be adopted if natural or irreversible man-induced constituent concentrations are higher than the specified chronic TVS, but the use is present. The EPA disapproved the ambient standard for zinc adopted by the WQCC for segments 3a, 4a, and 9b. They also disapproved the ambient standards for copper and iron in 9b.

Site-specific standards, acute or chronic, may be used for aquatic life segments where factors other than water quality substantially limit the diversity and abundance of species present. Site specific standards require a use attainability assessment to support such standards. The site specific approach was used for Zn in segment 4a, however that standard was also disapproved by EPA.

Table 9.1 Stream Segments Shown on CDPHE 1999 303(d) list

<date>

DRAFT Segment	Description	Use Impaired	Constituent(s)
2	Animas above Eureka	Metal source	Al, Cd, Cu, Fe, Pb
3a	Animas Eureka to Cement Ck	Aquatic life	Zn*
3b	Animas, Cement Ck to Mineral Ck	Metal source	Al, Cd, Cu, Fe, Pb
4a	Animas, Mineral Ck to Elk Ck	Aquatic life	PH, Cu, Fe, Zn*
4b	Animas, Elk Creek to Junction Ck	Aquatic life	Zn
7	Cement Creek	Metal source	Al, Cd, Cu, Fe, Pb
8	Mineral Creek above So. Mineral	Metal source	Al, Cd, Cu, Fe, Pb
9b	Mineral, So. Mineral to Animas	Aquatic life	PH, Cu*, Fe*, Zn

* Standards were disapproved by EPA on August 27, 1998

Narrative standards (Section 3.1.7(1)), may be applied if numeric standards are inappropriate. This provision was used for segments 2, 3b, 7, and 8 owing to natural sources of acid and metals that prevent attainment of aquatic life uses. Reduction of man-induced sources from these segments, however, is critical to the achievement of goals in downstream segments. The WQCC adopted and the EPA approved narrative standards for segments 2, 3b, 7, and 8.

Two methodologies are used to evaluate water quality in this UAA. The first is the 85th percentile methodology utilizing average hardness for those constituents whose TVS are a function of hardness. We use this method in order to be consistent with CDPHE practice. The second methodology eliminates the variation in concentration due to stream flow and seasonality which are the variables that account for most of the observed variation in concentration of constituents in surface water. This method also allows for evaluation of toxicological thresholds if hardness is added. We use this method to identify season, flow states, and duration of concentration which may impair classified uses.

Leib (2000) developed the water quality model for several mainstem and tributary segments in the upper Animas basin. The model uses discharge and season as the independent variables. Periodic functions describe seasonality using day of the year. A dummy variable, as in analysis of covariance, was used to test if remediation had altered water quality. If the model retains the dummy variable, $t_{\alpha/2} < 0.05$ for pre- post- remediation, it is concluded that there has been a change in water quality. This approach is described in Helsel and Hirsch, 1995. Year round monitoring at the gaging stations began in 1995, thus there is at least two years of pre-remediation data. The Leib model accounts for 12 to 86 percent of the variation (R^2) in constituent concentration. The highest R^2's are for hardness, Al, and Zn while the lowest is for Cd. Figure 9.1 shows the sites that were used to develop the model.

Table 9.2 includes data for the most recent three years, 1997 through 1999. These years correspond to the time period when several activities to improve water quality, including the Sunnyside Consent Decree and other remediation activities, began in the upper Animas, Cement, and Mineral Creek by SGC, the ARSG, and BLM. Table 9.2 compares the 85th percentile of representative water quality data for the UAA segments to the current standards and temporary modifications. Segments 2, 7, and 8 have narrative standards, therefore ambient conditions (85th percentile) that existed through 1994 are compared to water quality for the 1997 to 1999 period.

The concentrations in Table 9.2 were evaluated at four gaging stations and five secondary locations shown in Figure 9.1. The gaging stations have operated continuously since October 1, 1993 and are the most intensively sampled. The USGS collected monthly chemistry and flow data at the secondary stations during 1998 and 1999 to characterize the effect of stream flow and season on water quality at intermediate points for selected reaches. The secondary stations also establish baseline quality conditions that may be used to evaluate the effect of future remediation projects.

Table 9.2 shows the 85th percentile of Al, Cd, Cu, Fe, Mn, and Zn since October 1996 has increased in some cases. Higher levels are due to intensive monitoring during the winter period when stream flow is low and concentrations are higher. This is a better reflection of how the hydro-chemical system in the basin operates, not degradation of water quality. Very little winter data, except at A72, existed prior to 1995. Al was sampled only in the summer prior to 1995 at any location.

Segment 2

Some remediation has occurred in the headwaters of Segment 2, however water quality has generally remained the same at A33, the Animas River above Eureka, since 1994. Although there are differences in Cu and Zn as shown by the 85th percentiles, there is insufficient data to determine whether or not water quality has changed. Cd, Cu, and Zn remain above TVS for aquatic life.

Table 9.2a Comparison of ambient quality to TVS and adopted standards for Segment 2.

Site		pH	Al	Cd	Cu	Fe	Pb	Mn	Zn
	TVS				Not Applicable				
All	'91-'94	6.9	100	2.9	16		Bdl	800	700
A33	'98-'99	6.5	8	2.9	30	Bdl	Bdl	780	550

Segment 3a

The data at A 53 and A 60, the Animas River at Howardsville and below Arrastra Gulch respectively, in segment 3a shows a reduction in Cd, Cu, Mn, and Zn concentrations from segment 2. The dissolved Zn at these two locations is among the lowest in the basin. The higher Al at A 60 is due to more data collected during the winter low flow period. The concentration of Cd, Cu, Mn, and Zn greatly increases in segment 3a between Arrastra Gulch and Silverton at A68. The data from A 68, the most intensively sampled location on the segment shows levels of Al, Cd, Mn, and Zn are higher than the adopted standards.

Comparison of seasonally and flow adjusted concentrations of Cd, Cu, and Zn to pre-1997 data reveals no change in the concentration. The regression model suggests Mn concentration has increased since 1997. Higher concentrations of Cd, Cu, and Zn are the result of more data collected during the winter low flow and first flush periods. Figures 9.2 through 9.5 compare ambient concentration of Cd, Cu, Mn, and Zn to TVS using flow based hardness. Cd, Cu, and Mn exceed TVS for a three to four month period in the winter. Zn exceeds TVS year a round. Zn exceeds the ambient standard adopted by the WQCC during most of the winter period.

Table 9.2b. Comparison of ambient quality to TVS and adopted water quality Standards in segment 3a.

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Site		pH	Al	Cd	Cu	Fe	Pb	Mn	Zn
	TVS	6.5	87	1.0	11		3	1000	95
All	WQS	**6.5**	**87**	**1.7**	**11**	**132**	**3**	**1000**	**540**
A53	'97-'99	**7.0**	**83**	**2.1**	**4**	**54**	**Bdl**	**262**	**304**
A60	'97-'99	**6.6**	**150**	**2.4**	**5**	**Bdl**	**Bdl**	**214**	**277**
A68	'97-'99	**6.2**	**115**	**3.0**	**9**	**120**	**Bdl**	**2500**	**900**

Segment 7

The data from Cement Creek at Silverton, CC 48, shows that there has been a significant, $p<0.05$, reduction in the levels of Cd, Mn, and Zn since SGC began treating the flow of Cement Creek from above the American Tunnel in October 1996, figures 9.6 to 9.9. SGC treated most or all of the flow of Cement Creek above the American Tunnel except during the four high flow months when the stream flow exceeded the capacity of the treatment plant (Larry Perino, personal communication). The average Mn level, as determined by the flow/seasonally adjusted methodology, has been reduced even though the 85th percentile suggests an increase. Treating the flow of Cement Creek did not change the levels of Al, Cu, or Fe at Silverton, CC 48, figures 9.10 and 9.11. Levels of Al, Cd, Cu, Pb, and Zn remain acutely toxic to aquatic life in Cement Creek. Treatment of Cement Creek will end after SGC completes their obligations under the Consent Decree.

Table 9.2c. Comparison of ambient quality to TVS and adopted water quality Standards in segment 7.

Site		pH	Al	Cd	Cu	Fe	Pb	Mn	Zn
	TVS			Not applicable					
All	'91-'94	4.4	4300	5.4	110		20	1500	930
CC48	'96-'99	3.8	3164	2.3	84	4823	13	1824	817

Segment 8

Partial remediation at the Kohler-Longfellow and Carbon Lakes sites near Red Mountain Pass has reduced the levels of Cd, Cu, Pb, and Zn in segment 8, Mineral Creek above South Mineral Creek (M27). The effect of the remediation is noted in both the 85th percentile and flow/seasonally adjusted methodologies. The Middle Fork of Mineral Creek, downstream from the Kohler-Longfellow, is the main source of Al and Fe, so little reduction of these metals due to remediation is seen at in Mineral Creek above South Mineral at M27. Concentrations of Al, Cu, Pb, and Zn remain at levels acutely toxic to aquatic life in segment 8.

Table 9.2d. Comparison of ambient quality to TVS and adopted water quality Standards in segment 8.

Site		pH	Al	Cd	Cu	Fe	Pb	Mn	Zn
	TVS			Not applicable					
All	'91-'94	4.5	5200	3.2	190	6900	23	860	920
M27	'97-'99	4.3	5500	1.8	112	4417	6.6	783	

Segment 9b

The 85th percentile methodology shows that Al exceeds acute criterion (750 ug/l) for aquatic life at M34, Mineral Creek near Silverton. Cd, Cu, and Zn exceed chronic TVS, however they are equal to or lower than the temporary modifications adopted by the WQCC in 1995. The regression model, figure 9.12, shows that the level of Al is elevated for over four months during the winter. Cd exceeds TVS during the spring runoff, figure 9.13. Cu and Zn exceed TVS most of the year, figures 9.14 and 9.15. The benefits of partial remediation at Kohler-Longfellow and Carbon Lakes are measurable in Mineral Creek, at M 34. Cu and Zn levels are lower than the adopted temporary modifications. The regression model shows an average reduction in Cu and Zn of 11 and 98 ug/l, respectively, at M34.

Table 9.2e. Comparison of ambient quality to TVS and adopted water quality Standards in segment 9b.

Site		pH	Al	Cd	Cu	Fe	Pb	Mn	Zn
	TVS	6.5	87	1.4	15		7	1000	137
	WQS	6.5	87	1.7	57	3415	7	1000	544
M34	'97-'99	4.8	2097	1.6	49	3300	2	471	482

Segment 4a

Monitoring at A 72, the Animas River below Silverton, segment 4a, shows levels of Al, Cd, Cu, Fe, Mn, and Zn exceed water quality standards using the 85th percentile methodology. Comparing pre 1997 data with post 1997 data using the flow seasonal adjustment regression methodology shows the water quality has not changed over the 1991 to 1999 period. The higher levels of Al, Cu, Fe, Mn, and Zn are due to more data collected during the winter spring flush periods. The regression model shows Cd and Cu slightly exceed chronic TVS during portions of the year, figures 9.16 and 9.17. Al exceeds the chronic criterion for aquatic life for most of the winter, figure 9.18. Zinc exceeds the chronic TVS year a round and exceeds the temporary modification adopted by the WQCC during the winter.

Table 9.2f. Comparison of ambient quality to TVS and adopted water quality Standards in segment 4a.

Site		pH	Al	Cd	Cu	Fe	Pb	Mn	Zn
	TVS	6.5	87	1.2	13		5	1000	117
	WQS	6.5	87	1.6	13	390	5	1000	520
A72	'97-'99	5.8	554	2.0	20	2326	Bdl	1600	723

Segment 4b

Dissolved Cd, Cu, Pb, and Zn, in segment 4b as measured in the Animas River at Baker's Bridge, A75, are lower than the adopted standards. This may be a reflection of remediation activities undertaken since October 1996.

Table 9.2g. Comparison of ambient quality to TVS and adopted water quality Standards in segment 4b.

Site		pH	Al	Cd	Cu	Fe	Pb	Mn	Zn
	TVS	6.5	--	1.6	17		7	50	149
	WQS	6.5	--	1.6	17	300	7	210	182
A75	'97-'98	7.5	--	0.5	Bdl	--	Bdl	326	157

Summary

The higher than expected concentrations of dissolved Al and Zn in segments 3a, 4a, and 9b are the result of more intensive monitoring during the winter low flow and first flush periods. Samples obtained during these times since 1995 clearly shows variations in water quality related to stream flow and seasonal factors that were not accounted for when the 1994 goals were set.

Table 9.3 85th percentile by season--December-May and June-November

		PH	*Al*	*Cd*	*Cu*	*Fe*	*Pb*	*Mn*	*Zn*
3a	Su	6.4	70	1	5	120	Bdl	1100	420
	Wi	6.1	133	4.5	10	120	Bdl	3400	1179
4a	Su	6.1	80	.0	8.3	895	Bdl	1070	430
	Wi	5.5	752	2.3	21	2749	1.0	1960	752
9b	Su	6.1	88	0.4	7	1760	Bdl	310	239
	Wi	4.8	2568	1.8	54	3700	1.4	542	530

Higher concentrations of Al, Cd, Cu, and Zn per unit of discharge occur in the late winter early spring than at other times of the year. Zinc concentration elevates during the winter base flow period, peaking from around April 15 to the end of May at the start of the runoff period. Al concentration exceeds chronic criteria for aquatic life in segments 3a, 4a, and 9b from December through May and exceeds acute standards in segments 4a and 9b for the same time period. Cu concentration exceeds chronic TVS in segments 4a and 9b during the runoff period. Zn exceeds acute and chronic criteria in all three segments most of the year.

Assessment of sources

The water quality of the upper Animas reflects the combination of natural and man induced factors. Geologic processes that formed the San Juan caldera and subsequent circulation of fluids rich in sulfur and base metals provided the basis for the acid environment that exists today. Bove and others (2000) describes the area as being similar in nature to the acid-sulfate hydrothermal systems found in the Summitville and Lake City areas of Colorado. Oxidation of pyrite, the most widespread sulfide mineral, causes acid water, but contributes little in terms of base-metal content. Dissolved Cu and Zn originate from the oxidation of vein and disseminated base-metal sulfides, i.e enargite and sphalerite, (Bove and others, 2000). Aluminum is dissolved as a product of acid weathering of aluminosilicate minerals. Acidicwater, created from pyrite oxidation, increases the dissolution of all metals. Furthermore this acidic environment is ideal for acid loving bacteria (e.g. ..) that greatly increases dissolved metal concentrations while further lowering acidity through a biocatalytic process know as Acid Rock Drainage.

Early miners following veins that had been filled with sulfur and metal bearing fluids, exposed sulfide bearing minerals to oxygen in adits, stopes, and shafts. Exposure of sulfide minerals to oxygen whether through mine water or from dumps or mill waste is one of the processes leading to acid formation. When the acid waters come into contact with Al, Cd, Cu, Pb, and Zn minerals they dissolve and are transported to the streams. One of the challenges is to separate sources of acid and metals that are natural from those that have been aggravated by man's activities which might have the potential for remediation (i.e. "reversible").

Mine Related

Water quality investigations by the ARSG, including CDPHE, USGS, USFS, BLM, Sunnyside Gold Corporation, and other private interests, have investigated the sources of loading (discharge plus concentration) of various metals in the basin. Mine related sources include mine water from adits and shafts, waste dumps at the mine portals, and mill tailings. Over 120 adits within the upper basin have been sampled one or more times. Table 9.3 summarizes some of the important load characteristics of these studies. The American Tunnel on Cement Creek near Gladstone, historically was the largest source of load. Drainage from the American Tunnel has been treated since 1989. The tunnel was partially bulkhead sealed in late 1996, and is scheduled for complete closure in accordance with the Sunnyside Consent decree. Several other adits, including the Terry Tunnel (1996), Ransome adit (1998) on Eureka Creek, and the Sunbank (1993) and Gold Prince (1997) adits near the Animas headwaters have been sealed since investigations began in 1991.

Although the discharge of mine water tends to be relatively constant over the year, seasonal variation in the discharge rate in some mine water has been observed. One of the objectives of the ARSG, USGS, and SGC is to establish the variation in load over the annual cycle. This will be used to identify the more significant adits and to quantify the potential for lowering the in stream concentration by controlling mine water as it relates to seasonal variation in stream flow.

Waste rock from the mining process is a second source of metals. Waste rock includes dump material deposited near mine workings and mill tailings. Waste rock (dumps) at the mine sites are highly variable in their acid and metal producing capability. Waste rock from mine workings driven through non sulfide bearing minerals have little acid producing potential. Mill tailings, generally speaking, have the greatest acid generating capability because the rock is finely ground which exposes more surface area to oxidation. Moreover, rock transported to the mills were the major ore bearing minerals such as pyrite, sphalerite, galena, and enargite which have the richest metal content and the highest acid generating potential. Early mill technology often left large quantities of these base metals in the tailings, concentrating on recovery of the precious metals, gold and silver.

The potential for metal loading from dumps and mill tailings is greatest in the spring during snowmelt and from late season thunderstorms. Melting snow infiltrates and percolates through the waste piles recharging shallow ground water or directly runs off to nearby streams. Late season thunderstorms also increase metal loading from waste rock areas. Wirt and others (2000) measured the load of Al, Cd, Cu, Fe, and Zn from Prospect Gulch during a September thunderstorm, and found them to be one or more orders of magnitude higher during storm runoff conditions than during base flow. They also found the largest increases in loads corresponded to areas where waste-rock dumps were in close proximity to the stream.

Mill tailings have been consolidated to several areas along the Animas River mostly within segment 3a. Mill tailings at the Mayflower Mill (Ponds 1-4)have been capped and revegetated in accordance with Sunnyside's mine reclamation plan. SGC also removed historic mill tailings from Howardsville to their tailings pond number 4 near Silverton in 1997.

Mill tailings, from the South Fork of Cement Creek, were relocated to tailings pond #4 between 1990 and 1992. Analysis of data collected by SGC has shown that relocation of this pile resulted in a measureable decrease in the dissolved aluminum and dissolved iron concentration in South Cement Creek.

Extensive investigations of over _____ waste dumps by the DMG, USFS, BLM, ARSG, and Sunnyside since 1995 have identified the most significantly impactingdumps. Two dumps identified through the ARSG process have been partially remediated. Sunnyside covered and amended the Longfellow dump and relocated the Kohler dump on Red Mountain Pass in 1996-97. The ARSG, with the assistance of a Sec. 319 non point source grant, is currently relocating the dump at nearby Carbon Lakes to Pond #4 as well. Remediation of these three sites has resulted in a measurable reduction of dissolved cadmium, copper, and zinc in Mineral Creek at Silverton.

Other human impacts:

Failure of a large tailings pond at Eureka during a flood in the 1930's caused tailings to be deposited over a large area of the flood plain of the Animas River. Sediment movement in this reach of the Animas has caused the channel to aggrade , raising the base of the streambed by about one meter, since mining began(Vincent, 1999). The result of the aggradation was to obliterate the pre-mining morphology of the stream and destroy the willows that provided bank stability and riparian habitat (Milhous, 1999). Much of the tailings have been transported downstream and incorporated into stream sediments. SGC removed much the remaining consolidated tailings from terraces near the Animas River at Eureka in 1997. Church and others (1997) found concentrations of Pb, Zn, and Cu in bed sediments of the upper Animas River were four to six times higher than concentrations found in pre-mining bed sediments.

Other human activities in the basin have the potential to impact water quality. Roads used to reach the mine sites and for recreation are potential sources of sediment. . Alpine sections of the headwaters of the Animas, Mineral, and Cement Creeks have grazing allotments for sheep. Accelerated erosion of soils formed from decomposed sulfide minerals due to overgrazing is a potential source of metal and sulfide laden sediment.

The town of Silverton WWTP discharges to the Animas River above Mineral Creek. The ARSG sampled several sewer lines in town. Cadmium, copper, lead, manganese, and zinc were all found, however concentrations were lower than concentrations found in the River. The wastewater treatment plant is not a significant source of metals.

Groundwater

Groundwater as a source of metals to the Animas River and its tributaries was minimally evaluated before 1996. Recent investigations have shown that groundwater is a major cause of acid and metal loading. Loads from groundwater can be both natural and man induced. Identified sources include natural springs, fractures and faults, and movement of water through waste-rock.

Investigations of Mineral Creek and Cement Creek (Wright, 1999) identified large quantities of Al and Fe in springs from areas that are not affected or only minimally affected by mining. A large natural spring in the Middle Fork of Mineral Creek (M18) is the biggest contributor of dissolved Al and Fe to Mineral Creek. The Paradise Portal, a short distance upstream from the spring is the second largest source of dissolved Al and Fe to Mineral Creek. This shallow portal was probably abandoned due to the large volume of water encountered. Springs emanating from shallow prospects, such as the Ferrocrete and Imogene mines, in the Mineral Creek watershed, are large sources of Al and Fe. Tracer-injection studies by the USGS in 1997 found that the summation of the Zn load from tributary and mine sources was substantially less than the total load in three discrete reaches of Cement Creek where ground water inflow entered the stream along fractures (Kimball and others, 2000). High in the headwaters of the Animas watershed stream channels in Burrows and California Gulches, follow mineralized fractures and faults. Large increases in manganese and zinc loads not associated with surface expression of mining were noted in these areas (Herron and others, 1998).

Shallow wells, were driven into in the gravel in and around Silverton in order to obtain ground water samples that reflected the Animas, Cement and Mineral Creek flow regimes, Ground water from these wells showed varying concentrations of cadmium, copper, lead, manganese, and zinc. The highest concentrations of manganese and zinc, 66,000 and 7000 ug/l respectively, were found at the Silverton campground near the north end of town. The well at the Silverton campground is upstream from A68 and groundwater from this plume probably has an effect on the level of metals measured at A68. Zinc concentration averaged 385 ug/l in the well near the WWTP at the south end of town.

Load Analysis by Segments

One of the goals of the ARSG is to identify sources of metal loading and to estimate the water quality that would result if a number of sources were controlled. This estimate of attainable water quality would be used to judge the aquatic life that could be supported.

Data have been collected to estimate loads from adits, mine waste, natural springs, groundwater and other sources. These loads have been compared to loads in various segments of streams in the basin on a synoptic, seasonal, and annual basis. One important conclusion from the studies is that significant attenuation of some metals from the source to where they are measured downstream (reference).. Dye tracer synoptic studies done by the USGS in 1997, 1998, and 1999 demonstrated that the sum of measured loads is greater than what is measured at the four gaging stations. Two chemical processes, precipitation and sorption contribute to the attenuation (reference). The order of attenuation of target metals in the Animas basin from greatest to least are Pb, Al, Cu, Fe, Zn, Mn, and Cd.

Metals found in waters with low pH are mostly dissolved. Increasing the pH causes the metals to precipitate. The pH at which this occurs is different for each metal. Al, Cu, Fe, and Pb are among the first metals to precipitate, while Cd, Mn, and Zn require higher pH. The pH of Cement Creek (4.4 to 5.1) is low enough to keep most metals (except Pb) in the dissolved form. This is also largely true for Mineral Creek, especially during the winter months when the mean pH is 5.0. The pH of the Animas River on the other hand (6.5 to 7.8) is high enough to cause precipitation of all metals except cd, mn, and zn.

Recent laboratory studies by the USGS (Schemel and others, 1999) demonstrated that the fraction of Zn in the colloidal phase (precipitate) increases with increasing pH. Moreover, their laboratory studies showed that a greater fraction of zinc was in the colloidal phase when associated with high concentrations of Al and Fe colloids. The colloids are available for precipitation or coprecipitation. Schemel and others (1999) suggest that the natural mixing of Cement and Mineral Creek waters high in Al and Fe colloids waters with higher pH waters from the Animas may result in significant sorption of zinc onto Fe and Al colloids. This process of trace metal sorbtion likely occurs where ever the combination of waters rich in iron, aluminum, and trace metals are subjected to waters with less acidity.

DRAFT

Animas

Mining related (no distinction made between reversible and irreversible, see section XII)
  Adits
  Dumps
  Mill tailing and smelter slag
Other sources – roads, grazing, Silverton W.W. plant, stormwater load
Groundwater
Other unindentified sources including natural
(potentially use some site specific examples of

Cement

Mining related (no distinction made between reversible and irreversible, see section XII)
  Adits
  Dumps
  Mill tailing and smelter slag
Other sources – roads, grazing, Silverton W.W. plant, stormwater load
Groundwater
Other unindentified sources including natural
(potentially use some site specific examples of

Mineral

Mining related (no distinction made between reversible and irreversible, see section XII)
  Adits
  Dumps
  Mill tailing and smelter slag
Other sources – roads, grazing, Silverton W.W. plant, stormwater load
Groundwater
Other unindentified sources including natural
(potentially use some site specific examples of

Figures 9.2 to 9.5

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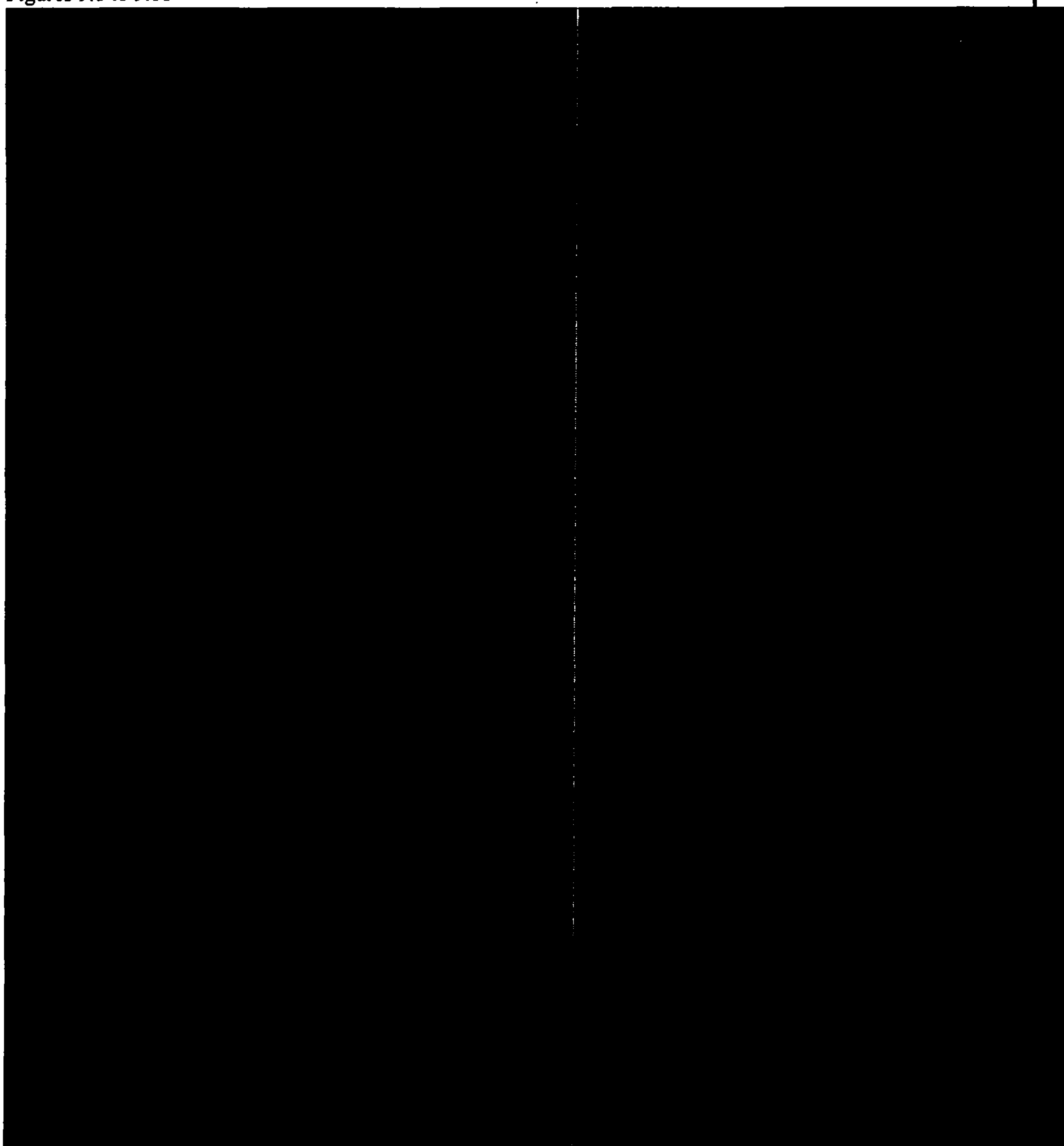

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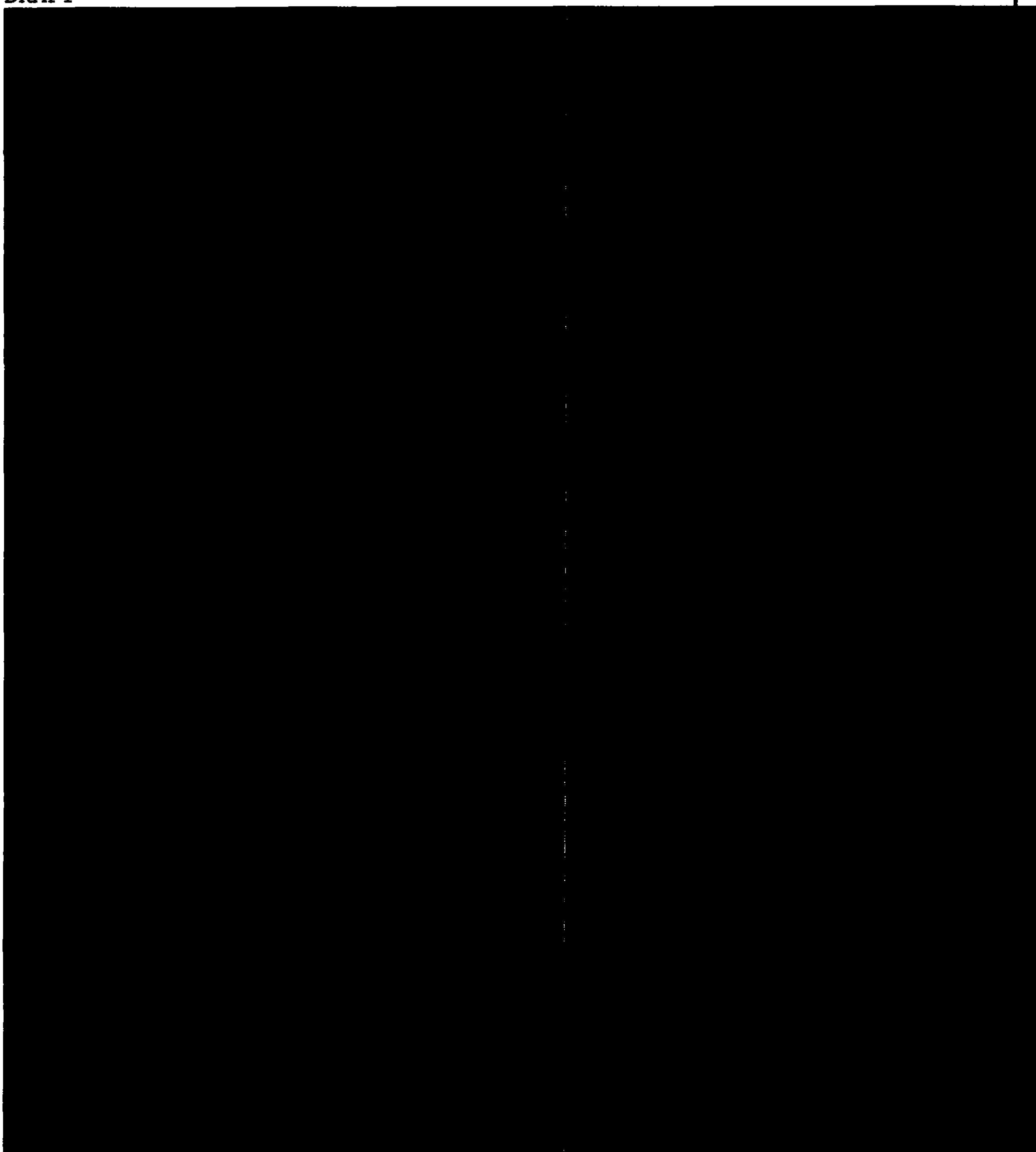

Figures 9.12 to 9.17

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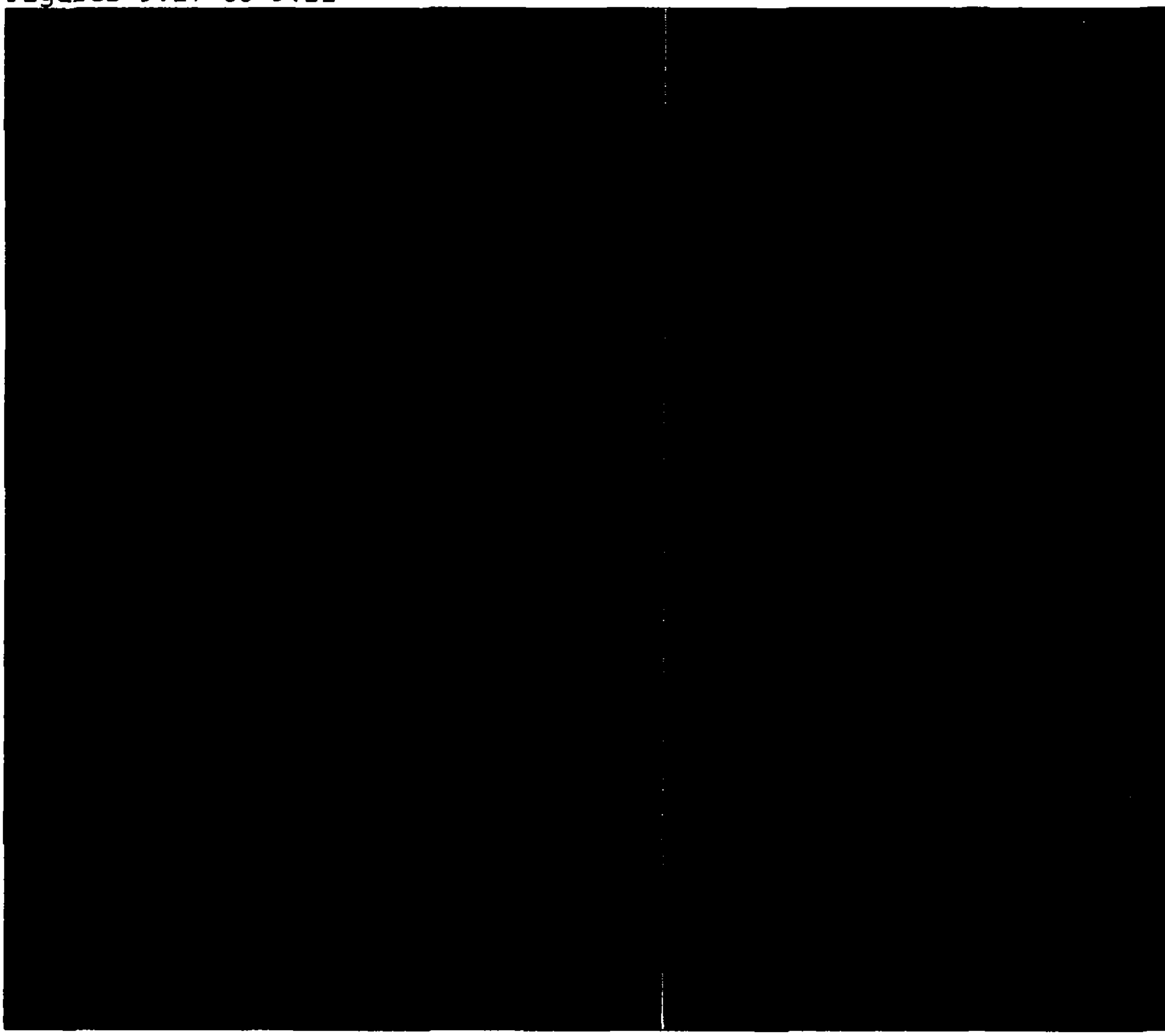

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wsimon@frontier.net on 07/23/2000 09:46:09 AM

To: silvertonstd@frontier.net, wgwright@usgs.gov, tstrain@uc.usbr.gov, tsluis@durangoherald.com, thennis@eazy.net, toms@bitstorm.net, fearneng@rmi.net, spowers@uc.usbr.gov, sfsh2o@frontier.net, rob_robinson@co.blm.gov, blair_r@fortlewis.edu, pbutler@frontier.net, pbvongue@usgs.gov, paul.krabacher@state.co.us, mbaum@castlenet.com, matt.sares@state.co.us, lwickstr@blm.gov, lperino@compuserve.com, kjleib@usgs.gov, jpt@frontier.net, john_besser@usgs.gov, james.herron@state.co.us, rogersoj@ci.durango.co.us, greg.parsons@state.co.us, gknapp@asarco.com, gthrash@co.blm.gov, gary.jennings@co.usda.gov, fking@southern-ute.nsn.us, david.r.gregory@usace.army.mil, daniel.beley@state.co.us, mpc_sw@frontier.net, sanjuancounty@frontier.net, craiii@csi.com, Carol Russell/EPR/R8/USEPA/US@EPA, camille.farrell@state.co.us, bruce.stover@state.co.us, bkcampbell@fortlewis.edu, jrowenjr@earthlink.net, "bkimball@usgs.gov"@frontier.net, billjones@frontier.net, bgoodhard@denver.echobay.com, Barbara_Hite@co.blm.gov, barb.horn@state.co.us, silverav@frontier.net, al_rae@yahoo.com, stephanie_odell@co.blm.gov

cc:

Subject:

ANNOUNCEMENTS:

1) There will be a special UAA work session on Monday night August 7th at 7:00 PM in the basement of the Miner's Union Hospital. Bob Owen will be up to discuss Chapter IX and the loading analysis. I think he will have the revisions to the Chapter ready beforehand, so I will send them out in advance. I believe Ken Leib will also be available at the meeting-his loading report is still under review but he can answer questions about it and it's comparability to Bob's work.

2) The won't be an August stakeholders meeting but instead on August 17, 2000 at 7:00PM we will be meeting at Town Hall to here some presentations from the USGS including modeling efforts and ??? Briant Kimball, DMG, and several others will be in town all that week doing tracers in the Upper Animas. This will be a good opportunity to discuss results of past projects.

- att1.htm

wsimon@frontier.net on 07/10/2000 09:04:06 AM

To: jrowenjr@earthlink.net, al_rae@yahoo.com, silverav@frontier.net, barb.horn@state.co.us, Barbara_Hite@co.blm.gov, bgoodhard@denver.echobay.com, billjones@frontier.net, "bkimball@usgs.gov"@frontier.net, bkcampbell@fortlewis.edu, bruce.stover@state.co.us, camille.farrell@state.co.us, Carol Russell/EPR/R8/USEPA/US@EPA, craiii@csi.com, sanjuancounty@frontier.net, mpc_sw@frontier.net, daniel.beley@state.co.us, david.r.gregory@usace.army.mil, fking@southern-ute.nsn.us, gary.jennings@co.usda.gov, gthrash@co.blm.gov, gknapp@asarco.com, greg.parsons@state.co.us, rogersoj@ci.durango.co.us, james.herron@state.co.us, john_besser@usgs.gov, kjleib@usgs.gov, lperino@compuserve.com, lwickstr@blm.gov, matt.sares@state.co.us, mbaum@castlenet.com, paul.krabacher@state.co.us, pbvongue@usgs.gov, pbutler@frontier.net, blair_r@fortlewis.edu, rob_robinson@co.blm.gov, sfsh2o@frontier.net, spowers@uc.usbr.gov, fearneng@rmi.net, toms@bitstorm.net, thennis@eazy.net, tsluis@durangoherald.com, tstrain@uc.usbr.gov, wgwright@usgs.gov, silvertonstd@frontier.net

cc:

Subject: Fw: More UAA files

Hello. I am re-sending an email I thought had gone out earlier but seems to have been lost in my computer. Perhaps you received this (Chapter 9) before but I can't tell if it was really sent. So here it is: Chapter 9 of the UAA. This is the chapter that determines the existing water quality and will be the basis for the Triennial Review in August. We will be asking for a hearing in March, 2001 to reclassify and adopt new standards based upon actual conditions presented in Chapter 9. The precise standards and scientific basis for what the recommendations will not be presented at the Triennial Review since they are works in progress; however, our preliminary analysis will be able to give indications on what the issues will be (e.g. aluminum in Segment 9b) and how we will support our recommendations for each segment.

So Chapter 9 is very important and it needs your review ASAP. Bob Owen, author of this chapter, has separated ground waters from surface waters and this approach may be used to support what can and cannot be done remediation wise. Bob Owen needs feed back this week. He also indicated he is unable to attend the July 20th meeting which is a big disappointment as it was our last meeting date before the triennial review. Bob will be available on July 17 and 18th and again on August 8-10th so we might have to have another meeting if you all desire.

Please read Chapter 9 carefully and reply and/or edit to me. Thanks, bill

----- Original Message -----
From: William Simon
To: Susan McIntyre ; SUSAN McIntyre ; Greg Parsons ; GREG PARSONS
Sent: Friday, June 16, 2000 7:12 AM
Subject: More UAA files

- att1.htm
- CHAPTER 9, June,00.doc
- Chapter 9 References.doc
- Figure 9.2 to 9.5 (1).doc
- Figures 9.6 to 9.8.doc

CHAPTER 9: EXISTING QUALITY AND SOURCES OF DEGRADATION

Many water quality standards for the Animas River basin changed as a result of the 1994 hearing. The changes, based on data collected between 1989 and 1994, reassessed the status of aquatic life and estimated the potential for establishing aquatic life in the Animas River and several of its tributaries. Several activities affecting water quality have occurred and new data has been collected since 1994. New data is used to

quantify seasonal and annual variations in loading from identifiable mining related sources,

improve estimates of metal contributions from all other sources,

evaluate seasonal variations in water quality at the four gaging stations, and

evaluate the effect of recent remediation projects on the chemistry of Mineral Creek, Cement Creek, and the Animas River.

These data, together with data from the earlier studies, will be used to establish water quality goals that may reasonably be achieved through restoration of disturbed sites. Alternative uses and standards that might be achieved through remediation are proposed. The UAA focuses on stream segments with aquatic life classifications and standards disapproved by EPA in their letter of September 1998 and/or are contained in the state's 1998 303(d) list. The list of stream segments that do not comply with the state's 303(d) list and EPA's 1998 disapproval letter are shown in Table 9.1

Table 9.1 Stream Segments Shown on CDPHE 1998 303(d) list

Segment	Description	Use Impaired	Constituent(s)
2	Animas above Eureka	Downstream aquatic life	Al, Cd, Cu, Fe, Pb
3a	Animas Eureka to Cement Ck	Aquatic life	Zn*
3b	Animas, Cement Ck to Mineral Ck	Downstream aquatic life	Al, Cd, Cu, Fe, Pb
4a	Animas, Mineral Ck to Elk Ck	Aquatic life	pH, Cu, Fe, Zn*
4b	Animas, Elk Creek to Junction Ck	Aquatic life	Zn
7	Cement Creek	Downstream aquatic life	Al, Cd, Cu, Fe, Pb
8	Mineral Creek above So. Mineral	Downstream aquatic life	Al, Cd, Cu, Fe, Pb
9b	Mineral, So. Mineral to Animas	Aquatic life	pH, Cu*, Fe*, Zn

* Standards were disapproved by EPA on August 27, 1998

Existing Quality

Chemical and physical water analyses have been done at several hundred sites within the basin. The purpose of this section is to evaluate and compare stream water quality with water quality standards and criteria used by the Colorado WQCC for aquatic life classifications. This section emphasizes selected sites where recurring analyses have been done in order to account for temporal variations in water quality. Data collected from 1997 through 1999 are compared to earlier data. This period was chosen to insure that the most recent data was used, and it follows the time when the SGC consent decree was implemented. The latter is important because several remediation projects have improved water quality in some segments.

Colorado's "Basic Standards and Methodologies" (5CCR 1002-31) uses a set of twelve water quality indicator parameters for review and standard setting purposes: dissolved oxygen, pH, unionized ammonia, fecal coliform, Ag, Cd, Cu, Pb, Fe, Hg, Se, and Zn. Dissolved oxygen (DO), unionized ammonia (NH3), and fecal coliform bacteria are associated with domestic or municipal waste water which has a negligible effect on waters in the upper Animas basin. These constituents are briefly discussed in the UAA because all are well within established criteria for all use classifications. Data for these constituents are available for the Animas River below Silverton, A72, prior to 1994 and a few sites above A72 (except fecal coliform)—See Appendix *XXXX*. The WQCD's earlier studies included analyses for Al, Cr, Mn, and Ni in addition to the metals specified above. Subsequent studies reduced or eliminated analysis for Ag, Hg, Se, Cr, and Ni because they were shown to have minimal or no effect on waters in the basin (WQCD, 1994).

The Appendix *XXXX* also includes analyses for major cations (Ca, K, Mg, SiO, Na) and anions (SO4, NO_x, CO3, and HCO3). Trace metal analyses for Sb, Vn, and Th were later requested by the EPA. These metals were rarely found (Farrell, 1996). EPA also requested that waters in the basin be screened for standard organic and pesticide residues. None were found in sediments, surface water, or ground water of the Animas or Cement Creek (Farrell, 1996).

Al, Cd, Cu, Pb, Fe, Mn, and Zn are the metals commonly found in the basin and are the focus of the UAA. WQCC criteria for pH have upper as well as lower criteria. Only the lower pH criteria are discussed in the UAA owing to acid conditions found in the basin.

Procedures for evaluating water quality and establishing standards are determined by the Colorado WQCC ("The Basic Standards and Methodologies for Surface Water" 5CCR 1002-31). Existing or ambient water quality is compared to TVS. The regulation

Ambient quality for most metals is determined from the dissolved fraction, which is the portion that passes defines ambient quality as the 85th percentile of representative data. If ambient quality is better than TVS for the classified use, TVS are adopted. Numeric standards for aquatic life are based on acute or chronic table value standards (TVS). Aquatic life TVS for Cd, Cu, Pb, Mn, and Zn vary with water hardness. Higher metal concentrations are tolerated at higher hardness values. The practice of the WQCD is to compare 85th percentile concentrations to TVS calculated from average hardness for the segment.

If natural or irreversible human-induced constituent concentrations are higher than the specified chronic TVS, but the classified use is supported, ambient standards, 85th percentile, may be adopted. The EPA disapproved the WQCC's ambient standards for Zn for segments 3a, 4a, and 9b that exceeded TVS aquatic life criterion because there was no proof that the high concentrations were irreversible. EPA also disapproved ambient standards for Cu and Fe in 9b for the same reason.

The WQCC regulations also provide for site-specific water quality standards. This methodology may be based on either acute or chronic criteria and, may be used for aquatic life segments if factors other than water quality substantially limit the diversity and abundance of species present. Site-specific standards require a use attainability assessment (UAA) to support them. The WQCC used the site-specific approach for Zn in segment 4a, however that standard was disapproved by EPA because of the uncertainty of the method used to develop it.

Narrative standards (5CCR 1002-31.7 (1)), may be applied if numeric standards are inappropriate. This provision was used for segments 2, 3b, 7, and 8 owing to high levels of acid and metals that prevent attainment of aquatic life uses. Reduction of man-induced sources from these segments, however, is critical to the achievement of goals in downstream segments. The WQCC adopted and the EPA approved narrative standards for segments 2, 3b, 7, and 8.

Data Analysis

Two methodologies are used to evaluate water quality in this UAA. The first compares the 85th percentile concentration to TVS, utilizing average hardness for those constituents whose TVS are a function of hardness, to chronic TVS. This method is consistent with CDPHE practice. *See Appendix xxxx.*

The second methodology examines the variation in concentration attributable to different stream flows and seasons of the year. These two factors account for most of the variation in solute concentration in surface water in the Upper Animas basin. This method allows for identification of flow states and periods when concentrations are likely to be the most toxic to aquatic life and to implement remediation strategies that will be most effective

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through a 0.45 micron filter. Standards for Hg are based on the unfiltered fraction. Standards for Fe use the unfiltered fraction for aquatic life and the filtered fraction for water supply.

for achieving UAA goals.

Metals are more toxic to aquatic life when hardness is low. Water hardness is least during runoff, thus some metals are more toxic during runoff. Higher metal concentrations may be tolerated by sensitive aquatic species during low flow periods owing to higher hardness. High metal concentrations during low flow are indicative of groundwater and adit related sources of metals whereas high concentrations during runoff are associated with metal sources from waste rock and the regional surface geology. Timing of the most toxic conditions to the most sensitive life stages of target aquatic life is also important for establishing UAA goals. The second method identifies the season, flow states, and duration of concentration, that may be limiting to certain aquatic species.

The second method uses multiple linear regression analysis to account for variations in stream flow and season. Leib (2000) describes the selection and transformation of the independent variables. The regression model uses discharge and day of the year as the independent variables, and is applied to several main stem and tributary segments in the Upper Animas basin. Stream flow is linearized by the use of a hyperbolic function. Seasonal changes in water quality are linearized by transforming julian dates with periodic functions (sine/cosine pairs). Accounting for variation in metal concentrations owing to different flow levels and seasonal differences in metal levels provides a more sensitive test for evaluating the effect remediation on changing water quality. Including a dummy variable, as in analysis of covariance, into the model was used to test if water quality changed between two periods, i.e. did remediation alter water quality. If the model retains the dummy variable, $t_{\alpha/2} < 0.05$ for pre- post- remediation, it is concluded that there has been a change in water quality. This approach is described in Helsel and Hirsch, 1995.

Regression methodology requires that concentration data be gathered over a wide range of flow conditions and throughout the year. Year round monitoring at four gaging stations, shown in Figure 9.1, began on October 1, 1993. These stations are generally sampled for water chemistry at least once a month. Several secondary stations on the Animas River, Cement Creek, and Mineral Creek were monitored monthly for chemistry and flow by the USGS during 1998 and 1999 to characterize intermediate points for selected reaches. The secondary stations also establish baseline quality conditions that may be used to evaluate the effect of future remediation. The Leib model accounts for 12 to 86 percent of the variation (R^2) in constituent concentration. The highest R^2's are for hardness, Al, and Zn while the lowest is for Cd.

Several remediation activities affecting water quality began in late 1996, including the Sunnyside Consent Decree and remediation activities, by the ARSG, and BLM. Tables 9.2 a-g compares the 85th percentile concentration in the UAA segments to the WQS the WQCC adopted before recent remediation and chronic TVS criteria for the last three years, 1997 through 1999.

Segments 2, 7, and 8 have narrative standards, therefore ambient conditions (85th percentile) that existed prior to 1997 are compared to water quality for the 1997 to 1999 period.

Tables 9.2 a-g show that the levels of Al, Cd, Cu, Fe, Mn, and Zn for the 1997 to 1999 period are higher than the WQS on several segments. Higher concentrations are the result of more intensive monitoring during the winter period when stream flow is low. The more recent data provides a better reflection of how the hydro-chemical system in the basin operates, and is not due to degradation of water quality. Very little winter data, except at A72, existed prior to 1995. Al, which has proven to be an important water quality factor during parts of the year, was sampled only in the summer before 1995.

Segment 2

Segment 2 is the headwaters of the Animas River and extends to Maggie Gulch about 2 miles south of the Eureka town site. Principal tributaries include California, Placer, and Burrows and Eureka Gulches. Many mine sites are located within the reach. The failure of a large tailings dam at Eureka in the 1930's deposited mill tailings in the channel and flood plain of the Animas River causing significant degradation of the valley bottom from Eureka to below Maggie Gulch. Most water quality data has been collected from A33, the Animas River above Eureka Gulch.

The USGS sampled A33 on 12 different dates in 1998-1999. Water quality has generally remained the same since 1994, even though some remediation has occurred in the headwaters of Segment 2. Although the 85th percentiles show differences in Cu and Zn, the data is insufficient to determine if the water quality has changed. Cd, Cu, and Zn remain above chronic TVS for aquatic life

Table 9.2a Comparison of ambient quality to TVS and adopted standards for Segment 2. All units except pH are in micrograms per liter.

Site		pH	Al	Cd	Cu	Fe	Pb	Mn	Zn
	TVS				Not Applicable				
	WQS	6.9	100	2.9	16		Bdl	800	700
A33	'98-'99	6.5	8	2.9	30	Bdl	Bdl	780	550

Segment 3a

This segment is the mainstem of the Animas from Maggie Gulch to Cement Creek at Silverton. Investigations during the early '90's showed that the segment supports several age classes of brook trout. Several mill sites and reclaimed mill tailings are located on terraces of the valley floor along the reach. Except for mill tailings remaining from the flood of the 1930's, there are no mill tailings immediately adjacent to the Animas River. SGC relocated some mill tailings from terraces at Eureka and Howardsville to the Mayflower tailings site in 1997. Recent water quality data in segment 3a has been collected at at Howardsville downstream from Cunningham Creek (A53), below Arrastra Gulch (A60), and in Silverton above Cement Creek (A68).

The data at A 53 and A 60 show a reduction in Cd, Cu, Mn, and Zn concentrations from segment 2. A 53 was sampled on 15 different dates and A 60 on 8 different dates during 1998-1999. The dissolved Zn at these two locations is among the lowest in the basin. The higher Al at A 60 shown in Table 9.2b reflects the concentration during the winter low flow. No winter data was obtained at either A53 or A60 before 1998. The concentration of Cd, Cu, Mn, and Zn greatly increases in segment 3a between Arrastra Gulch and Silverton (A68).

A 68, the most intensively sampled location (n>90) on the segment, shows levels of Al, Cd, Mn, and Zn are higher than the adopted standards. Comparison of seasonally and flow adjusted concentrations of Cd, Cu, and Zn to pre-1997 data, however reveals no change in the concentration. The flow/season adjustment model suggests the Mn concentration has increased since 1997. Higher concentrations of Cd, Cu, and Zn reflect water quality conditions during the winter low flow and first flush periods. This is shown in Figure 9.2. The ambient concentration of Cd, Cu, and Mn, compared to chronic TVS using flow based hardness shows that these metals exceed TVS for a three to four month period in the winter. Zn exceeds TVS year a round, and exceeds the ambient standard adopted by the WQCC during most of the winter period.

Table 9.2bi. Comparison of ambient quality to TVS and adopted water quality Standards in segment 3a. All units except pH are in micrograms per liter.

Site		pH	Al	Cd	Cu	Fe	Pb	Mn	Zn
	TVS	6.5	87	1.0	11		3	1000	95
	WQS	6.5	87	1.7	11	132	3	1000	540
A53	'97-'99	7.0	83	2.1	4	54	Bdl	262	304
A60	'97-'99	6.6	150	2.4	5	Bdl	Bdl	214	277
A68	'97-'99	6.2	115	3.0	9	120	Bdl	2500	900

Arrastra Gulch

Arrastra Gulch, a tributary to segment 3a, was inadvertently not included in any of the segments in the upper basin. The area around Silver Lake at the headwaters of Arrastra Gulch was mined into the 1920's, and many remnants of the mining days are still present. Access to the headwaters and to Silver Lake is only by foot travel at this time. Water quality of Arrastra Gulch is similar to segment 3a, the Animas River. Five samples are available with an average hardness of 70 mg/l.

Table 9.2bii. Comparison of ambient quality to TVS in Arrastra Gulch. All units except pH are in micrograms per liter.

Site		pH	Al	Cd	Cu	Fe	Pb	Mn	Zn
	TVS	6.5	87	1.0	11		3	1000	95
Arrastra		7.4	Bdl	1.4	8	13	Bdl	Bdl	200

Segment 3b

This segment is a short reach of the Animas River between Cement Creek and Mineral Creek. It follows the east edge of Silverton. There are no water quality stations on segment 3b. Low pH (3.8 to 4.5) combined with Al and Fe rich water from Cement Creek mixes with high pH (6.0 to 7.3) water in the Animas River. Mixing of the waters from the two streams causes rapid formation of Al and Fe colloids, which begin to settle in the reach. Schemel and others, (1999) found that Zn was rapidly adsorbed by the Al and Fe colloids in this reach.

Segment 7

Segment 7 incorporates the entire Cement Creek watershed. The American Tunnel (AT) at Gladstone about 7 miles upstream from Silverton is an important dividing point in the watershed. SGC has treated the discharge from the AT since the 1960's, and levels of treatment periodically increased over the years. By 1989, the treated discharge from the AT added an insignificant quantity of metals to Cement Creek. The AT was partially sealed in 1996, and SGC has used part of the additional treatment capacity of the plant to remove metals from Cement Creek above the AT. All or most of the flow of Cement Creek above the AT has been run through the treatment plant for about eight months of the year (Larry Perino, personal communication).

South Cement Creek joins the mainstem a short distance below the AT. South Cement Creek is an important source of Fe and Zn.

Large additions of Al, Cu, Fe, and Zn to Cement Creek have been identified between Prospect Gulch and Silverton. USGS tracer studies (Kimball, 2000) identified major inputs from Ohio, Minnesota, and Prospect Gulches whose watersheds lie within and drain the acid-sulfate system which dominates the west side of the Cement Creek watershed (see Chapter 4).

Data from Cement Creek at Silverton, CC 48, shows that SGC reduced the levels of Cd, Mn, and Zn since treating Cement Creek above the AT began in October 1996. Except for Mn, this is reflected in 85th percentile data shown Table 9.2c. Multiple regression analysis of the data at CC48, controlling for stream flow, season, and pre- post-consent decree shows statistically measureable ($p < 0.05$) reductions in levels of Cd, Mn, and Zn, Figures 9.6 to 9.9. The average Mn level, after accounting for variation caused by stream flow and seasonality, shows that it has been reduced even though the 85th percentile suggests an increase. Treating the flow of Cement Creek did not change the levels of dissolved Al, Cu, or Fe at Silverton, CC 48, Figure 9.3 Levels of Al, Cd, Cu, Pb, and Zn remain acutely toxic to aquatic life in Cement Creek. Treatment of Cement Creek will end after SGC completes their obligation under the Consent Decree.

Table 9.2c. Comparison of ambient quality to TVS and adopted water quality Standards in segment 7. All units except pH are in micrograms per liter.

Site		pH	Al	Cd	Cu	Fe	Pb	Mn	Zn
	TVS				Not applicable				
	'91-'94	4.4	4300	5.4	110	5480	20	1500	930
CC48	'96-'99	3.8	3164	2.3	84	4823	13	1824	817

Segment 8

Segment 8 is the main stem of Mineral Creek, which begins on Red Mountain Pass and extends to the confluence of South Mineral Creek. This part of the Mineral Creek watershed, which drains the acid-sulfate geologic type discussed in Chapter 4 and Appendix *XX*, has the fewest number of mines, but some of the highest metal concentrations in the Upper Animas basin, Table 9.2d. The Red Mountain Pass area, which includes the Kohler-Longfellow site, is the largest single source of Zn anywhere in the basin. The site also produces large quantities of Cd and Cu.

Segment 8 also includes the Middle Fork of Mineral Creek, which contains large deposits of quartz-sericite-pyrite (QSP) discussed in Chapter 4. The QSP part of the watershed had no producing mines, but is the largest source of acid water, Al, and Fe in the Mineral Creek basin. Kimball's (2000) tracer study of Mineral Creek found that Cu from the Red Mountain Pass area was re-dissolved when it mixed with acid water from the Middle Fork.

Partial remediation at the Kohler-Longfellow and Carbon Lakes sites near Red Mountain Pass has reduced the levels of Cd, Cu, Pb, and Zn in segment 8, Mineral Creek above South Mineral Creek (M27). The effect of the remediation is noted in both the 85th percentile and flow/seasonally adjusted methodologies. The Middle Fork of Mineral Creek, downstream from M13, is the main source of Al and Fe in Mineral Creek. Concentrations of Al, Cu, Pb, and Zn remain at levels acutely toxic to aquatic life in segment 8.

Table 9.2d. Comparison of ambient quality to TVS and adopted water quality Standards in segment 8. All units except pH are in micrograms per liter.

Site		pH	Al	Cd	Cu	Fe	Pb	Mn	Zn
	TVS				Not applicable				
	'91-'94	4.5	5200	3.2	190	6900	23	860	920
M13	'98-'99	6.3	67	4.9	79	128	*	452	1207
M27	'97-'99	4.3	5500	1.8	112	4417	*	783	723

* Detection limits for Pb, 30 ug/l, are too high to be used.

Segment 9b

This segment is the mainstem of Mineral Creek from South Mineral Creek, segment 9a, to the confluence with the Animas River. The WQCC adopted the aquatic life use and numeric standards for Al, Cd, Cu, Fe, Pb, Mn, and Zn based on remediation of metal loading from the Red Mountain Pass area. EPA disapproved ambient standards for Cu and Fe because they were not consistent with requirements in the federal water quality standards regulations (40CFR 131.11).

The 85th percentile methodology shows that Al exceeds acute criterion (750 υg/l) for aquatic life at M34, Mineral Creek near Silverton. Cd, Cu, and Zn exceed chronic TVS, but they are equal to or less than the temporary modifications adopted by the WQCC in 1995. Considering the effects of stream flow and season, the level of Al is about 3 times higher than the acute criterion for aquatic life for over four months during the winter, Figure 9.4. Cd exceeds TVS during the spring runoff, figure 9.13. Cu and Zn exceed TVS most of the year, Figure 9.4. The benefits of partial remediation at Kohler-Longfellow and Carbon Lakes are measurable in Mineral Creek, at M 34. Cu and Zn levels are lower than the adopted temporary modifications. After accounting for the effects of stream flow and season, the regression model shows an average reduction in Cu and Zn of 11 and 98 ug/l, respectively, at M34.

Data collected since 1995 shows the importance of Al as a contaminant in this section of Mineral Creek. Most of the dissolved Al is from the Middle Fork of Mineral Creek. The pH of Mineral Creek at M34 is less than 5.5 more than 50% of the time during the winter. Colloidal Al forms when the pH rises above 5.5 (Nordstrom and others, 1999). Most of the Al remains dissolved for the winter. High Fe concentrations accompany the high Al values observed at M34. The large sources of Fe are from the same QSP sources as the Al.

Table 9.2e. Comparison of ambient quality to TVS and adopted water quality Standards in segment 9b. All units except pH are in micrograms per liter.

Site		PH	Al	Cd	Cu	Fe	Pb	Mn	Zn
	TVS	6.5	87	1.4	15		7	1000	137
	WQS	6.5	87	1.7	57	3415	7	1000	544

M34	'97-'99	4.8	2097	1.6	49	3300	2	471	482

Segment 4a

Segment 4a extends from the confluence of Mineral Creek and the Animas River to Elk Creek about 5.5 miles downstream. Water quality investigations of the early 1990's found only minimal aquatic life in this segment. Dissolved Zn was thought to be the main cause of impairment, followed by dissolved Cd and Cu. Further the effects of Al and Fe, which continue to precipitate in the segment, were also thought to contribute to the impairment. Improvement of this reach so that it is capable of supporting aquatic life is one of the goals of the ARSG.

Monitoring in segment 4a at A 72, the Animas River below Silverton, indicates levels of Al, Cd, Cu, Fe, Mn, and Zn exceed water quality standards using the 85th percentile methodology. More data collected during the winter and spring flush periods have resulted in higher levels of Al, Cu, Fe, Mn, and Zn. Comparison of pre 1997 data with post 1997 data using the flow seasonal adjustment regression methodology shows the water quality has not changed over the 1991 to 1999 period. The regression model shows Cd and Cu slightly exceed chronic TVS during portions of the year, Figure 9.5. Al exceeds the chronic criterion for aquatic life for most of the winter, Figure 9.5. Zinc exceeds the chronic TVS year a round and exceeds the temporary modification adopted by the WQCC during the winter.

Table 9.2f. Comparison of ambient quality to TVS and adopted water quality Standards in segment 4a. All units except pH are in micrograms per liter.

Site		pH	Al	Cd	Cu	Fe	Pb	Mn	Zn
	TVS	6.5	87	1.2	13		5	1000	117
	WQS	6.5	87	1.6	13	390	5	1000	520
A72	'97-'99	5.8	554	2.0	20	2326	Bdl	1600	723

Segment 4b

This segment extends from Elk Creek in the Animas River canyon to Junction Creek near downtown Durango. Investigations by the ARSG (Simon and others, 1996) and the USFS did not identify additional sources of metals within the canyon reach. Metal concentrations decrease as metal free water flows into the Animas River. Conceentrations of Al, Cu, Fe, and Zn are further attenuated as the pH rises. Church and others (1999) found deposits of metal rich sediment in terraces in the canyon, indicating that early mining activity had affected the segment. The Animas River exits the canyon about 27 miles below Elk Creek near Baker's Bridge.

Sand and gravel mining, agriculture, and urbanization in the Animas Valley replaces hardrock mining as the factors that impact to water quality after the river leaves the canyon. Water quality in segment 4b is monitored by the Colorado River Watch program at Baker's Bridge (A75), Trimble Lane (A89), and Durango High School (A90).

Dissolved Cd, Cu, Pb, and Zn, in segment 4b as measured in the Animas River at the upper most station, Baker's Bridge (A75), between 1997 and 1999 are lower than the adopted standards. This improvement may be a reflection of remediation activities undertaken since October 1996. Segment 4a, at A72, is a chemically active area owing to mixing of waters with different pH and metal content. Partitioning of metals between the dissolved and colloidal state is active in the reach. Further downstream at A75 most of the colloids will have settled out which may account for the improvement. The most recent data shows that TVS are met for all constituents in the Animas River at A89 and A90.

Table 9.2g. Comparison of ambient quality to TVS and adopted water quality Standards in segment 4b. All units except pH are in micrograms per liter.

Site		pH	Al	Cd	Cu	Fe	Pb	Mn	Zn
	TVS	6.5	--	1.6	17		7	50	149
	WQS	6.5	--	1.6	17	300	7	210	182
A75	'97-'98	7.5	--	0.5	4	--	Bdl	326	159
A89	'97-'98	7.1	--	0.3	5	--	--	173	120
A90	'97-'98	7.6	--	0.2	4	--	--	143	112

The WQS for Fe is a non mandatory drinking water standard

The ARSG should consider proposing 4b be resegmented at Baker's Bridge.

Summary

Water quality monitoring between 1997 and 1999 found concentrations of Al and Zn exceeded the standards adopted by the WQCC in 1995 using the 85th percentile methodology in segments 3a, 4a, and 9b. The higher than expected levels of dissolved Al and Zn are the result of more intensive monitoring during the winter low flow and first flush periods. Multiple regression analysis of the data collected at four gaging stations between 1991 and 1999 clearly shows that the exceedances occur during low stream flow and during the winter months. Stream flow and seasonal factors were not specifically addressed when the 1994 standards and goals were set.

Table 9.3 85th percentile by season

		PH	*Al*	*Cd*	*Cu*	*Fe*	*Pb*	*Mn*	*Zn*
3a	Jun-Nov	6.4	70	1	5	120	Bdl	1100	420
	Dec-May	6.1	133	4.5	10	120	Bdl	3400	1179
4a	Jun-Nov	6.1	80	.0	8.3	895	Bdl	1070	430
	Dec-May	5.5	752	2.3	21	2749	1.0	1960	752

9b	Jun-Nov	6.1	88	0.4	7	1760	Bdl	310	239
	Dec-May	4.8	2568	1.8	54	3700	1.4	542	530

Higher concentrations of Al, Cd, Cu, and Zn per unit of discharge occur in the late winter early spring than at other times of the year. Zinc concentration elevates during winter base flow, reaching a maximum from around April 15 to the end of May when the peak runoff period begins. Al concentration exceeds chronic criteria for aquatic life in segments 3a, 4a, and 9b from December through May and exceeds acute standards in segments 4a and 9b for the same period. Cu concentration exceeds chronic TVS in segments 4a and 9b during the runoff period. Zn exceeds acute and chronic criteria in all three segments most of the year. Flow and seasonal factors that affect the concentration of priority metals will dictate remediation strategies and the ability to meet water quality goals for aquatic life.

Remediation activities undertaken by SGC, the ARSG, and others show measureable reductions in Cd and Zn in Cement Creek at Silverton and in Cd, Cu, and Zn in Mineral Creek at Silverton have resulted since October 1996.

Assessment of sources

The water quality of the upper Animas reflects the combination of natural and man induced factors. Geologic processes that formed the San Juan caldera and the subsequent circulation of fluids rich in sulfur and base metals, as described in Chapter 4 of the UAA, is the basis for the acid environment that exists today. Oxidation of pyrite, the most widespread sulfide mineral in the basin, is the source of most of the acid water. Mining exposed additional sulfur bearing minerals to oxygen in adits, stopes, shafts, which lead to acid mine drainage. Waste rock, rich in pyrite, removed from the mines is another source of acid water. Minerals containing Al, Cd, Cu, Pb, and Zn that contact acid waters dissolve and the metals are transported to the streams. The purpose of this section is to identify principal sources of acid water and metals that are naturally occurring and those that have been aggravated by man's activities, and have the potential for remediation (i.e. "reversible").

Groundwater

Groundwater, as a source of metals to the Animas River and its tributaries, was minimally evaluated before 1996. Recent investigations have shown that groundwater is a major source of acid and metal loading to parts of Cement Creek, Mineral Creek, and the Animas River. Loads from groundwater are both natural and human induced. Identified sources include natural springs, fractures and faults, mine openings, and movement of water through alluvial material and waste-rock.

Herron found large increases in Mn and Zn along stream reaches not associated with surface expression of mining high in the headwaters of the Animas watershed (Herron and others, 1998). Their sampling showed increases in Mn and Zn loads in Burrows and California Gulches where the stream channels were in areas with substantial fractures and faults.

Much of the Animas valley between Eureka and the canyon south of Silverton is filled with glacial and alluvial sediment deposits, creating a potentially large groundwater reservoir. Ore mills between Eureka and Silverton supplied huge quantities of tailings that were stored on the floodplain and terraces. Vincent and others (1999) estimated that near Eureka the fine fraction of streambed and floodplain sediments deposited after 1900 is composed of two-thirds mill tailings. Tracer studies by the Paschke and others (2000) concluded that most of the Zn loading to the Animas River between Eureka and Silverton was from groundwater (un-sampled flow) that entered the river near sites containing mill tailings.

Tracer-injection studies by the USGS in September 1997 found that only about half of the Zn load in Cement Creek was from identifiable tributary and mine sources (Kimball and others, 2000). The difference is attributed to loads contributed from ground water. Kimball identified three discrete reaches of Cement Creek (Prospect Gulch, the iron bog, and the lower bog) where the increased Zn load corresponded to areas with substantial fracture patterns. Prospect Gulch contains several mines that drain, thus the contribution of Zn may be from water unaffected by mining and mined sources. No mine development was present in the fault area of the lower bog, so its represents a non-mining contribution to the Zn load of Cement Creek (Kimball and others, 2000). A second source of subsurface inflow measured by Kimball in Cement Creek was in areas with large alluvial fans, such as those found at the bottom of Minnesota and Ohio Gulches (Kimball and others, 2000).

Investigations of Mineral Creek (Wright, 1999) identified large quantities of Al and Fe in springs from areas that are not affected or only minimally affected by mining. A large spring in the Middle Fork of Mineral Creek (M18, nicknamed the Red Trib because of red staining of the channel) is the source of most of total (non-filtered) Al and Fe in Mineral Creek in the winter that is shown in Figure 9.8. The Paradise Portal, a short distance upstream from the spring, is a second source of total Al and Fe to Mineral Creek. This shallow portal was probably abandoned due to the large volume of water encountered in a natural underground fracture or fault was reached. The metals from this source quite possibly were naturally present because the collapsed portal excludes oxygen, a necessary element for AMD. Springs emanating from other shallow prospects, such as the Ferrocrete and Imogene mines, in the Mineral Creek watershed, are large sources of Al and Fe and are treated as ground water sources rather than adit. ***(We need to make a decision here as to treating White Death, Imogene and Ferrocrete as adits or as natural ground water. Are there similar sites in Cement Creek or Upper Animas?)***

About two percent of the watershed above A72 is ungaged at A68, CC48, and M34. This area, which is under lain with gravel, is a measureable source of water and metals to A72. Summed stream flows at A68, CC48 and M34 at differing times of the year are less than the discharge measured at A72. Tracer-injection studies by the USGS in 1997 and 1998, Kimball and others (2000) found that both discharge and loads of SO4, Cu, Mn, and Zn, not attributable to surface inflow, increased near A72.

Shallow wells, driven into in the gravel in and around Silverton provide an overview of the Animas, Cement and Mineral Creek ground water flow regimes. Water from these wells showed varying concentrations of Cd, Cu, Pb, Mn, and Zn. The highest concentrations of Mn and Zn, 66,000 and 7000 ug/l respectively, were found at the Silverton campground near the north end of town. The well at the Silverton campground is upstream from A68 and groundwater from this area probably has an effect on the level of metals in surface water measured at A68 and A72. Zinc concentration averaged 385 ug/l in the well near the WWTP at the south end of town.

Mine Related

Water quality investigations by the ARSG, CDPHE, USGS, USFS, BLM, SGC, and other private interests, have sampled many mine related sources in the basin for the target metals. Mine related sources include water draining from adits and shafts, waste rock at the mine portals, and mill tailings. The discharge from over 120 adits within the upper basin have been sampled one or more times. Samples of rock from over 200 waste areas have been subjected to leach tests to determine acid generating potential and metal content. The purpose of the sampling is to estimate which sources contribute the greatest loads of target metals.

The philosophy of the ARSG has been to address those areas that contribute the greatest load. A source with a low concentration and high discharge may produce as significant a load as a source that has high concentration but low discharge. Examples of the former and the latter are zinc loads from the Silver Ledge Mine on South Cement Creek (C=0.7 mg/l, Q=1cfs) and the Kohler Mine on Red Mountain Pass (C=270 mg/l, Q=0.02cfs), respectively. Sites with low concentrations may be less cost-effective treat owing to the volume of water. Recent investigations at the Mary Murphy Mine in the Arkansas basin of Colorado, demonstrated that the majority of the metal loading came from a fraction of the discharge (Bruce Stover, Personal communication). Although loads from adits are one of the most obvious sources to identify, they are not necessarily the easiest to solve. Legal liabilities, remoteness of many adits, operating costs, and the current state of technology all must be evaluated in any solution.

Several adits in the upper Animas basin have already been sealed or the discharge is treated. The AT, located on Cement Creek near Gladstone, historically was a large source of metals. Drainage from the AT has been treated at varying levels since the

1960's. Removal of the largest quantities of metals began 1989. A bulkhead, placed in the tunnel in late 1996, partially sealed the discharge. Complete closure of the AT is scheduled in accordance with the Sunnyside Consent decree. Several other adits, including the Terry Tunnel (1996) and Ransome adit (1998) on Eureka Creek, and the Sunbank (1993) and Gold Prince (1997) adits near the Animas headwaters have been sealed.

Surface Runoff

Waste rock from the mining process is a second source of metals. Waste rock includes dump material deposited near mine workings and mill tailings. The DMG, USFS, BLM, ARSG, and SGC have sampled over 200 mine waste piles since 1995 and identified the sites most likely to affect water quality. Details of investigations of mine adits and waste rock are found in Herron and others (1998, 1999, and 2000).

Many factors determine the amount of metals that may be contributed to streams from waste rock in the upper Animas basin. Composition and mineralogy of the host rock is one factor. Waste rock from mine workings driven through non-sulfide bearing minerals, has little acid producing potential. Workings driven on vein are major sources of acid rock drainage. Both types of material may be present in the same dump.

Mill tailings have a higher acid generating capability because finely ground rock exposes more surface area to oxidation. Moreover, rock transported to the mills contained the major ore bearing minerals such as pyrite, sphalerite, galena, and enargite which have the richest metal content and the highest acid generating potential. Early mill technology concentrated on recovery of gold and silver, which often left large quantities of the base metals in the tailings.

A third factor is location of the waste rock in relation to surface and ground water. The potential for metal loading from waste rock is greatest in the spring during snowmelt and from late season thunderstorms. Melting snow infiltrates and percolates through the waste piles recharging shallow ground water or directly runs off to nearby streams. Late season thunderstorms also increase metal loading from waste rock areas. The load of Al, Cd, Cu, Fe, and Zn from Prospect Gulch in the Cement Creek watershed increased one or more orders of magnitude during September storm runoff conditions. The largest increases in loads corresponded to areas where waste-rock dumps were in close proximity to the stream (Wirt and others, 2000). The potential impact of waste rocks situated far from a stream has proven most difficult to evaluate. Discharge from adits or runoff can easily enter surrounding colluvium, emerging at some distant, lower elevation. Surface water that infiltrates and percolates through the waste pile may result in appreciable natural attenuation of some metals. Conversely, additional metals could be added while percolating through the ground depending on the local geologic conditions.

An intensive investigation of the Mayday mine waste pile in the Cement Creek watershed

(Stanton, 2000) found the highest concentrations of Cu, Pb, and Zn were associated with secondary minerals at 2-3 meters depth in the waste pile. He also found large numbers of iron- and sulfur-oxidizing microbes, and secondary Fe minerals at depth in the waste dump indicating that metals are mobile in the sub-surface. Because water is available on a sporadic basis at the Mayday dump—and many other dumps in the basin—rates of weathering reactions and mineral dissolution are sporadic as well (Stanton, 2000).

Most mill tailings have been relocated and consolidated to several areas along the Animas River mostly within segment 3a. Mill tailings at the Mayflower Mill (Ponds 1-4) have been capped and revegetated in accordance with SGC's mine reclamation plan. Mill tailings, from the South Fork of Cement Creek, were relocated to tailings pond #4 between 1990 and 1992. Data collected by SGC from the South Fork of Cement Creek (CC17) shows that relocation of this pile is resulting in a measureable decrease in the dissolved aluminum and dissolved iron concentration in South Cement Creek. SGC removed over 100,000 cubic yards of tailings from the Eureka floodplain in 1996 and relocated historic mill tailings from Howardsville to tailings pond # 4 near Silverton in 1997.

Waste rock from two sites, identified through the ARSG process, have been partially or completely remediated. SGC covered, amended and vegetated the Longfellow dump and relocated the Kohler dump on Red Mountain Pass to #4 pond in 1996-97. The ARSG, with the assistance of a 319 non point source grant, is currently relocating the dump at nearby Carbon Lakes to Pond #4. Remediation of these three sites has resulted in a measurable reduction of dissolved cadmium, copper, and zinc in Mineral Creek at Silverton.

Other human impacts:

Failure of a large tailings dam at Eureka during a flood in the 1930's spread tailings over a large area of the flood plain of the Animas River. Sediment deposited in this reach of the Animas has caused the channel to aggrade , raising the base of the streambed by about one meter, since mining began (Vincent, 1999). The result of the aggradation was to obliterate the pre-mining morphology of the stream and destroy the willows that provided bank stability and riparian habitat (Milhous, 1999). Most of the tailings have been transported downstream and incorporated into stream sediments. SGC relocated about 100,000 cubic yards of the remaining tailings from terraces near the Animas River at Eureka in 1997. Church and others (1997) found concentrations of Pb, Zn, and Cu in bed sediments of the Upper Animas River were four to six times higher than concentrations found in pre-mining bed sediments. See Section IV Mining History.

Other human activities in the basin have the potential to impact water quality, especially within the acid-sulfate and quartz-sericite-pyrite regions of Cement and Mineral Creek watersheds. Exposure of fresh sulfide minerals to air, water, and microbial action are especially critical because it could increase the production acid water and higher metal loads in nearby streams. Roads used to reach the mine sites and for recreation are potential sources of sediment. Alpine sections of the headwaters of the Animas, Mineral, and Cement Creeks have grazing allotments for sheep. Accelerated erosion, caused by improper grazing, is one mechanism that could lead to additional acid water production in selected areas.

Silverton's waste water treatment plant discharges to the Animas River above Mineral Creek. The ARSG sampled several sewer lines in town. Cadmium, copper, lead, manganese, and zinc were all found, however concentrations were lower than concentrations found in the River. The wastewater treatment plant is not a significant source of metals. Cold, swift water of the Animas minimizes the potential for DO problems. Similarly, low water temperature and low pH in the Animas also minimizes any potential for unionized ammonia. Fecal coliform from the waste water plant could affect recreational use of the river, however recreational use is confined to high flow periods when dilution is maximal.

Load Analysis by Segments

One of the goals of the ARSG is to estimate the water quality that would result if a number of sources were remediated. This estimate of attainable water quality will be used to determine the aquatic life potential.

Load analysis has several different objectives. The first objective is to identify the sources, i.e. groundwater, adits, and seasonal or intermittent contributions from waste rock or surficial geology. The second objective is to identify and rank sites that produce the largest quantities of the target constituents. The third objective is to estimate the water quality that could be achieved if the loading from priority sites was controlled. Identification and treatment of a single source in the upper Animas basin will not produce downstream results that can be measured in most cases.

A seasonal load analysis, based on months, was done at the three upstream gaging stations--A68, CC48, and M34. The purpose of the analysis is to examine the relative contributions of groundwater, adit, and surface runoff, waste rock plus natural, to the concentration of Al, Cu, Fe, and Zn. Using the detailed site-specific studies done in the basin, estimates of future water quality can be made and effective strategies developed to meet water quality goals. The contributions of target metals from natural groundwater establish the base level. Similarly runoff/run-on controls are most effective during and immediately after snow melt and rainfall events, so these factors establish limiting water quality conditions.

The load analysis was done for total (un-filtered) metals. Metals in low pH water are mostly dissolved. Increasing the pH results in the formation of colloids and causes the

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Multiplying the constant 5.4 mg/l cfs gives the load in pounds per day.

metals to precipitate. The pH at which this occurs is different for each metal. Al, Cu, and Fe, are among the first metals to precipitate, while Cd, Mn, and Zn require higher pH. Evidence of whitish Al precipitate is seen in the headwaters of the Animas, parts of Cement Creek, the Animas below Cement Creek, and the Middle Fork of Mineral Creek. Orange Fe precipitate is seen in Cement Creek, Mineral Creek and the Animas River between Cement Creek and Elk Creek. The pH of Cement Creek (4.4 to 5.1) keeps most metals in the dissolved form. This is also true for Mineral Creek, especially during the winter months when the mean pH is 5.0. The pH of the Animas River (6.5 to 7.8) is high enough to form colloids of all metals except Cd, Mn, and Zn.

Recent laboratory studies by the USGS (Schemel and others, 1999) demonstrated that the fraction of Zn in the colloidal phase (precipitate) increases at higher pH. Their laboratory studies showed that a greater fraction of zinc was in the colloidal phase when associated with high concentrations of Al and Fe colloids. The colloids are available for precipitation or co-precipitation. Schemel and others (1999) suggest that mixing water of Cement and Mineral Creek that are high in Al and Fe colloids with higher pH waters from the Animas may result in significant sorption of Zn onto Fe and Al colloids. The process of trace metal adsorbtion likely occurs where ever the combination of waters rich in Al, Fe, and trace metals are mixed with water having less acidity.

Solute loads measured at A68, CC48, and M34 are stable during November, December, January, and February when stream flow is sustained by the discharge of groundwater and mine water from adits. Drainage from acid rock in waste piles and shallow alluvial material is minimal under the winter snow pack. Discharge and concentration of metals from several mines with draining adits have been sampled in the winter so that an estimate of the groundwater load is obtained by subtracting a seasonally adjusted adit load. The results of the analysis for groundwater for Al, Cu, Fe, and Zn, shown in Figures 9.6 to 9.8, have been converted back to concentration to reflect the conditions encountered by aquatic life.

The total Al load from groundwater, shown in Figure 9.6, is higher than the chronic criterion for aquatic life for a part of the year, however owing to the higher pH in the Animas. Only a small percentage of the Al is dissolved. The Fe meets both total recoverable and dissolved criteria. The Zn concentration in groundwater exceeds TVS for three to four months of the year.

Groundwater sources of total Al, Cu, Fe, and Zn in Cement Creek exceed aquatic life criteria for most months of the year, Figure 9.7. The low pH in Cement Creek means that most of these metals are also dissolved. The projections for Cement Creek assume that SGC will not be treating the discharge of Cement Creek above the AT.

Figure 9.8 shows that most of the total Al and Fe in Mineral Creek is from groundwater sources and is minimally or not associated with mining. Although total Al is high for most of the year, its biggest effect on aquatic life is during the winter when the pH is low. The Fe concentration exceeds TVS in both dissolved and total recoverable forms. Cu and Zn sources from groundwater are minor at M34. The projections in Figure 9.8 include SGC's remediation activities on Red Mountain Pass.

The load from many adits varies over the year. Most adits with significant loads have been sampled at both low and high flow. A few adits with winter access, such as the Kohler, Mayday, and Forest Queen, were sampled monthly. The average annual cyclic variation in adit loads measured in the upper Animas basin is shown graphically in Figure 9.XX. Figures 9.6 through 9.8 show the relative contributions Al, Cu, Fe, and Zn from adits in each of the sub-watersheds. Data on individual adits is summarized in ***Appendix xxxx Prioritization Table***? Adits account for the highest percentage of Cu and Zn load in Mineral Creek and the lowest percentage in the Animas River above Silverton (measured at A68). The percentage of Al and Fe from adits in all three sub-basins is relatively small.

Separation of natural and human-induced sources of loading from surface runoff and shallow groundwater requires great familiarity with the watersheds. Zn increases in the Animas earlier that in Cement and Mineral Creek and has a higher peak. As few surface inputs of Zn have been identified, widespread mill tailings between Eureka and Silverton must be suspected, Figure 9.6.

Cu, Fe, and Zn from surface sources are a significant amount of the load measured at CC48 for part of the year. Synoptic studies indicate that these metals are from mined and un-mined areas.

A water quality model was developed for the basin that uses concentration and discharge values from the four gages on the Animas River (A68), Cement Creek (CC48), Mineral Creek (M34), and the Animas River below Silverton (A72). The discharge and date of interest are entered for A72. The discharge at A72 is distributed among A68, CC48, M34 and groundwater from the Silverton area using the historical stream flow relationships that exists among the streams. The loads from the three upstream gages, plus the groundwater component for the Silverton, area are summed. The accuracy of the model at different flow states is checked by comparing the concentration of the specific metal at A72 to the mass balance concentration of the upstream stations. Results are presented on a monthly basis using average monthly stream flow at A72.

DRAFT

6/16/00

References

Bove, D. J., Mast, M. A., Wright, W. G., Verplank, P. L., Meeker, G. P., and Yager, D. B. 2000. Geologic control on acidic and metal-rich waters in the southeast Red Mountains area near Silverton, Colorado. U. S. Geological Survey Open-File Report 00-034.

Church, S. E., Kimball, B. A., Fey, D. L., Ferderer, D. A., Yager, T.J., and Vaughn, R. B. 1997. Source, transport, and partitioning of metals between water, colloids, and bed sediments of the Animas River, Colorado. U. S. Geological Survey Open-File Report 97-151.

Farrell, Camille M. S. 1996. Site inspection sampling activities report Cement Creek watershed, San Juan County, Colorado. Colorado Division of Hazardous Materials and Waste Management.

Helsel, D. R. and Hirsch, R. M. 1995. Statistical Methods in Water Resources. Elsevier, Amsterdam.

Herron, J., Stover, B., Krabacher, P., and Bucknam, D. 1997. Mineral Creek feasibility investigations report, upper Animas River basin. Colorado Division of Minerals and Geology.

Herron, J., Stover, B., Krabacher, P., 1998. Cement Creek reclamation feasibility report, upper Animas basin. Colorado Division of Minerals and Geology.

Herron, J., Stover, B., Krabacher, P., 1999. Reclamation feasibility report, Animas River above Eureka. Colorado Division of Minerals and Geology.

Herron, J., Stover, B., Krabacher, P., 2000. Reclamation feasibility report, Animas River below Eureka. Colorado Division of Minerals and Geology.

Kimball, B. A., Runkel, R.L., Walton-Day, K., Bencala, K. E. 2000. Assessment of metal loads in watersheds affected by acid mine drainage by using tracer injectiOn and synoptic sampling: Cement Creek, Colorado, USA. (in press).

Kimball, B. A., Schemel, L. S., Cox, M. J., and Gerner, L. J. 2000. Loading and Chemical Reactions metals entering the Animas River between Silverton and Elk Park, San Juan County, Colorado. (in press).

Nordstrom, D. K., Alpers, C. N., Coston, J. A., Taylor, H. E., McCleskey, R. B., Ball, J. W., Ogle, S., Cotsifas, J. S. and Davis, J. A. 1999. Geochemistry, toxicity and sorption properties of contaminated sediment and pore waters from two reservoirs receiving acid mine drainage. U. S Geological Survey Water Resources Investigations Report 99-

4018A.

Owen, J. R., 1997. Water quality and sources of metal loading to the upper Animas River basin. Colorado Department of Public Health and Environment, Water Quality Control Division.

Paschke. S.S., Kimball, B. A., and Runkel, R. L. 2000. Quantification and simulation of metal loading to the upper Animas River, Eureka to Silverton, San Juan County, Colorado, September 1997 and August 1998. (in press).

Schemel. L. E., Kimball, B. A., and Bencala, K. E. 1999. Colloid formation and the transport of aluminum and iron in the Animas River near Silverton, Colorado. U. S Geological Survey Water Resources Investigations Report 99-4018A.

Simon, W. S. and others.1996)

Smith, K. S., Walton-Day, K., and Ranville, J. F. 1999. Considerations of observational scale when evaluating the effect of, and remediation strategies for, a fluvial tailings deposit in the Upper Arkansas River Basin, Colorado. U. S Geological Survey Water Resources Investigations Report 99-4018A.

Stanton, M. R. 2000. The role of weathering in trace metal redistributions in the Mayday Mine dump near Silverton, Colorado. U. S. Geological Survey Open-File Report 00-034.

Vincent, K. R, Church, S. E., and Fey, D. L. 1999. Geomorphological context of metal-laden sediments in the Animas River floodplain, Colorado. U. S Geological Survey Water Resources Investigations Report 99-4018A.

Water Quality Control Division. 1994. Exhibit 3, upper Animas Water Quality Classifications and Standards Proposal. Colorado Department of Public Health and Environment.

Wirt, L., Leib, K. J., Mast, M. A., and Evans, J. B. 2000. Chemical-constituent loads during thunderstorm runoff in a high-altitude alpine stream affected by acid drainage. U. S. Geological Survey Open-File Report 00-034.

Witters, H. E., Van Puymbroeck, S., Stouthart, A. J. H. X., and Bonga, S. E. W. 1996. Physiochemical changes of aluminum in mixing zones: mortality and physiological disturbances in brown trout. Environmental Toxicology and Chemistry v. 15.

Yager, D. B., Verplank, P. L., Bove, D. J., Wright, W. G., and Hageman, P. L. 2000. Natural versus mining-related water quality degradation to tributaries draining Mount Moly, Silverton, Colo. U. S. Geological Survey Open-File Report 00-034.

Chapter VIII – Metal Loading Processes

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High metal concentrations are impairing potential uses in the Upper Animas Basin. Where do the metals come from and why is there so much metal in the Animas as opposed to other watersheds? Are these high metal concentrations natural or caused by human activity? This chapter addresses these important questions.

Most of the Basin lies within the caldera of an old volcano. Volcanic activity is the initial geologic process for deposition of high concentrations of metals in the ground. These high concentrations are the reason miners came to the area. Only a few other areas in the state have seen as much volcanic activity over such a large area.

Certain geologic (erosion), chemical and biological processes cause the metals to dissolve and move into streams. Human activities such as mining, road building, development, and grazing can accelerate the natural processes. Thus, the sources of high metal concentrations in the Basin are a combination of natural and human activities.

Several attempts have been made to distinguish and quantify the amounts from each of these two sources. Unfortunately, the task has proven too difficult and costly so far. What these studies have shown is that there are some very significant natural sources of metals and that, at least in the past, mining activity substantially increased the metal loading to the Animas River. These studies are discussed later in the chapter below.

Geology

Metal loading processes start with the geology. Sources of metals, both natural and human-related, can readily be predicted by determining where those metal occur in the rock type. Here is a short description of the Basin geology from Bruce Stover of the Division of Minerals and Geology. A more detailed version is in the Appendices.

> The Animas River headwaters drain the Silverton Caldera, a Tertiary-aged volcanic center on the western margin of the regional San Juan Volcanic Field. In Oligocene through Miocene time, the Silverton Caldera was a focus of repeated volcanic eruptive activity. Hundreds of cubic miles of ash flows and lava were erupted upon a surface of older Paleozoic and Mesozoic sedimentary rock, and Precambrian metamorphic and igneous basement rocks. Through the middle Tertiary, an extensive, thick volcanic complex was formed, encompassing all of the present Animas Basin watershed. During periods of volcanic quiescence, retreat of magma from beneath the domed-up center caused widespread subsidence and subsequent collapse of a roughly ten-mile-diameter ring-shaped caldera within the larger volcanic field. Subsequent periods of eruptive activity each caused renewed uplift and doming of the caldera, followed in time by subsidence along the bounding ring-fault fractures as volcanic activity waned. These repeated volcanic episodes formed marginal ring-fault fractures, associated breccia pipes, and swarms of faults tangential and radial to the margin of the volcanic center.

Following cessation of volcanic activity, ground and surface waters began infiltrating and circulating in the cooling mass of volcanic rock. Heat from the cooling magma below set up broad, regional convection systems, circulating hot hydrothermal fluids through the subsurface for millions of years. Through time, these fluids chemically altered the original rock mass, and became enriched in metals derived from the volcanic and surrounding pre-volcanic country rock. Eventually, mineralizing solutions reached threshold geochemical temperature-pressure conditions, leading to deposition of several types of rich sulfide ores containing silver, lead, zinc, copper, and gold. The sulfide ores were preferentially deposited within and around the existing fissures, faults, and breccia pipes formed millions of years before. As a result, much of the rock in the Silverton Caldera complex is highly mineralized and hydrothermally altered, particulary along the margins of the caldera, and in the vicinity of major fissure vein systems.

Through the late Tertiary and to present day, regional uplift and subsequent erosion of the Colorado Plateau has cut deeply into the volcanic pile. Thousands of feet of overlying rock have been stripped away, revealing the roots of the volcanic center. Canyons around the margin of the caldera, such as the Animas River and Uncompahgre Gorge, have cut deeply into the underlying strata, exposing much older Paleozoic and Precambrian rock beneath the volcanic deposits.

The Animas watershed drains roughly three-quarters of the total extent of the Silverton Caldera. Extrusive sequences of volcanic ash-flow tuffs and flow breccias, and dacite –to-rhyodacite lava flows and domes underlie essentially the entire watershed. These rocks belong to the Silverton Volcanic series, and underlying San Juan Formation. The Silverton series has been further subdivided into mapable formations in the Silverton Caldera. On the southern and eastern margins of the caldera, Paleozoic and older Precambrian rock are exposed beneath the volcanic flows. Intruded upward into the volcanic flows within the caldera, but particularly along its margins, are younger stocks, plugs, dikes, and sills of a variety of igneous rock.

The high alpine terrain in the Animas watershed has been deeply scoured and sculpted by glaciers during the past 40,000 years. Mineral Creek and the Animas River flow in deep U-shaped valleys with flat floors, which were scoured along the faulted caldera margins they followed. Tributary gulches head in cirque basins, which hosted hanging valley glaciers that joined the main stem glacier hundreds of feet above the present valley floor. During this period, glacial ice extended down valley all the way to Durango.

Exposed bedrock outcrop with thin patchy soils covers an estimated 70% of the surface in the basin. Unconsolidated surficial deposits on the valley floors consist of remnant patches and aprons of glacial till, outwash and stream alluvium, and peat and organic bog deposits in wetland areas. Talus, scree, and rock glacier deposits mantle extensive areas of mountain slopes beneath cliffs and outcrops, where they have formed from continuous rock-fall. Debris fans composed of coarse, bouldery alluvium are commonly found at the mouths of steep ravines and tributary streams where they join the main valley. Isolated landslide deposits occur on steep slopes throughout the basin, and colluvial deposits mantle many of the lower valley footslopes below timberline.

All the volcanic rocks in the San Juan Volcanic Depression were extensively propylitized and altered on a regional scale, prior to sulfide ore deposition. "Propylitic" alteration is a term used to describe a particular type of mineralogic and chemical change that occurs by circulation of aqueous hydrothermal solutions through the original volcanic rock mass. Propylitic alteration adds carbon dioxide and water to the rock mass, resulting in mineralogical changes to the rocks. This alteration is typified by the formation and addition of chlorite, calcite, and clays in weakly altered rocks, to epidote, albite, and chlorite in the stronger phases. Propylitic alteration has resulted in a dull green or greenish gray color to virtually all of the volcanic rocks in the Animas watershed.

Regional acid-sulfate alteration occurs in the Animas watershed, and can be correlated directly with observed stream water quality. Rocks near some sections of the structural margin of the caldera and around volcanic breccia pipes have been highly altered by gaseous acid-sulfate and hydrothermal processes. Acid-sulfate processes have subjected the rock to attack and leaching by hot sulphurous gases and solutions moving upward along the structural margin of the Silverton Caldera. These hydrothermal processes have leached most of the base minerals from the rocks, while introducing such large amounts of sulphur and metal sulfides, that this type of mineralized terrain is readily distinguished from the surrounding regional propylitic alteration. Volcanic flows in the Red Mountain area forming the northwestern part of the caldera were so strongly altered and leached that little remains except silica, kaolinite, and sulfate and sulfide alteration products. Virtually all potential buffering minerals in the country rock have been leached away, leaving the quartz-allunite-pyrite alteration assemblage characteristic of the Red Mountain District. Bleaching of the rocks and subsequent surficial oxidation of the sulfides through geologic time has resulted in the brilliant red, orange, and yellow staining which characterizes many parts of the district.

Over much of the eastern margin of the watershed, acid-sulfate processes do not seem to have been as prevalent. There are only a few localized areas of naturally pyritized country rock in the headwaters of the upper Animas, or in the tributary watersheds draining the eastern half of the basin, as compared to Cement and Mineral Creek watersheds. On the eastern side of the basin, base minerals remain in the volcanic rock, and the greater abundance of carbonate minerals in the veins and country rock provide better buffering capacity to the hydrologic system in this area. This geology translates to better water quality in the gulches draining the eastern part of the basin, and fish are present in many of the streams.

The geology of tributary watersheds in the Animas Basin can be directly associated with observed water quality in the streams draining them. Streams which drain mineralized, acid-sulfate altered watersheds have been found to have consistently poorer background water quality than streams draining non-altered watersheds. Adit discharges from mines in acid-sulfate altered areas generally have higher metals concentration and acidity than discharges from adits in non-or weakly altered areas. In several cases, it is apparent that faults and other geologic structures associated with the mineralized areas may still be functioning as preferential groundwater flow paths, discharging metals laden groundwater to the surface streams.

Figure 8-1 shows the specific areas where most of the alteration has occurred. The acid-sulfate alterations are concentrated in the upper Mineral Creek drainage (Red Mountain) and the western side of the Cement Creek drainage. These areas contribute substantial metal loading, especially zinc. Western areas in the Mineral Creek drainage have sustained powerful Quartz-Sericite-Pyrite alterations and produce large loads of aluminum. Other highlighted areas show weak sericite, vein-related alterations that also contribute substantial metal loading.

Most of these altered areas were heavily mined and produce the majority of acid drainage. Other parts of the Basin have also been sites of substantial mining activity, but the drainage is far less problematic.

FIGURE 8-1

Chemical and Biological Processes

The generation of acid water and subsequent metal loading is caused by certain natural chemical and biological processes. When sulfide minerals mix with oxygen and water, they oxidize producing acid. This reaction also produces elements which are acted upon by certain acid loving bacteria through a biocatalytic process which generates sustantially more acid. Pyrite is the most widespread sulfide mineral in the Basin, but there are others.

Oxidation of pyrite causes acid water, but contributes little in terms of base-metal content. Dissolved Cu and Zn originate from the oxidation of vein and disseminated base-metal sulfides, *i.e* enargite and sphalerite, (Bove *et al.*, 2000). Aluminum is dissolved as a product of acid weathering of aluminosilicate minerals. Acidic water dissolves the metals and can carry them into the water ways. This process is ongoing unless acid buffering minerals such as limestone are present and offset the acid reactions.

Human Activities that accelerate metal loading

Any activity the exposes sulfides to oxygen and water can accelerate the natural acid reactions. Cutting roads up a hillside may open up sulfide veins. Heavy grazing may reduce soil cover which can lead greater acid generation. But mining practices in particular tend to increase exposure.

Early miners followed veins that had been filled with sulfur and metal bearing fluids and exposed sulfide bearing minerals to oxygen in adits, stopes, and shafts. These workings created conduits for groundwater to leach out along the walls and ceiling and drain out to the surface. Getting rid of water in the workings was and is a problem in many mines.

As the miners dug, much of the removed material was dumped directly outside of the adits and portals in waste rock piles. In some places, the waste rock piles are quite benign, containing few acid-generating sulfides and metals. In other locations, where miners worked rich veins, the piles may have a high acid potential. Piles with high acid potential may become large sources of metals particularly if they are situated in a gulch or stream, or in front of an adit draining acidic water into the piles.

Mill tailings are another potential source of metals. High grade ore was processed in mills. After targeted metals were removed, the material left over was dumped somewhere. This material is finely crushed, increasing the surface area that may be exposed to air and water. It is also more likely to contain sulfides and metals than waste rock piles.

Natural Versus Human-Caused Metal Loading

There has been an ongoing debate over how much of the metal loading in the Basin is due to naturals sources and how much is caused by human activities. The amount of natural loading will have some bearing on how much effort should be spent remediating human sources.

Unfortunately, we have no water quality data dating to a time before there was mining in the Basin. Trying to separate precisely what is natural and what is due to human activities of the past and today is virtually impossible. However, we can use more indirect methods to at least get a sense of the magnitude of what may be natural and what isn't.

Historical Reports

Black (1994) (Appendix XX) compiled quotes from various reports and newspaper articles about fishing and the Animas beginning in the late 1870's. There appears to have been good trout populations in Animas around Durango in the late 1800's. Fish were stocked in the Animas above Silverton with great success and trout ponds were constructed for raising fish. Locals recognized that trout would not do well in the mineralized drainages of Mineral and Cement Creeks. The accounts do not describe if trout were in Basin pre-stocking. There is a substantial cascade on the Animas below Rockwood (twenty miles above Durango) which may be a fish barrier to the upper part of the river.

Around the turn of the century, water quality Animas became significantly degraded throughout the length of the river. The culprit was mill tailing which were dumped directly into the river above Silverton. One Durango paper continually called for lawsuits and injunctions to shut down the mining industry in San Juan County. Water samples were taken and sent off for testing, but the results are unknown.

In addition, the town dump which included dead horses and sheep was located on the banks of the river, below the high water mark. Each spring it would conveniently disappear. Durangoans were horrified by the practice. Of course, Durango was dumping its own raw sewage directly into the river just below town.

Apparently often discussed lawsuits were never filed. Smelters for the mined ore were located in Durango and were the mainstay of the economy. The Durango City Council decided to pursue other water supply options instead and started the process to bring water over a low divide from the Florida River drainage. Durango still gets about 85% of its potable water from the Florida today. The other 15% comes from the Animas, and that percentage is growing. (Groening, 1994?)

Black's compilation of articles matches well with Jones (2000) (Appendix XX), a summary of historic mining and milling practices in San Juan County. Jones distinguishes between four different mining periods by milling technologies and practices. During the first period, 1871-1889, mining was very small scale and only high grade ore was removed. There was little milling and ore was generally shipped out directly to smelters. Any mined material that wasn't high grade was either discarded in the mines or tossed out in waste rock piles by the entrance. Zinc was not accepted by smelters because it was difficult to smelt. Thus it was left behind. Many of these old piles still contain metals that can be leached out with precipitation.

Mining production jumped upward significantly during the next period, 1890-1914. Technologies such as tramways and electricity for compressors made mining much easier. Silver and base metal prices fluctuated, but were frequently high enough to warrant large investments. The larger mines developed drainage problems and portals were constructed to remove water.

Although much of the ore was still hand sorted for high grade material, low grade ore went to new mills. Up to twelve stamp mills operated in the Basin during certain years. The stamps pulverized the ore and produced a muddy slime of discarded material called tailings. The tailings were disposed of in the river creating Durango's problems. With the mills, low-grade ore was more profitably mined, because most of the ore didn't need to be shipped. But it also produced much more waste. Zinc was still difficult to smelt and was usually discarded.

World War I marked the beginning of a new era. The demand for base metals, especially zinc, skyrocketed, and flotation mills began to be built in the basin. The flotation mills removed metals much more efficiently than older methods. It is hard to tell if this technology had positive or negative environmental consequences. A high percentage of metal could be removed from a ton of ore, but as a result, "bulk" mining began and more tailings were produced. Technologies for removing rock were also improving.

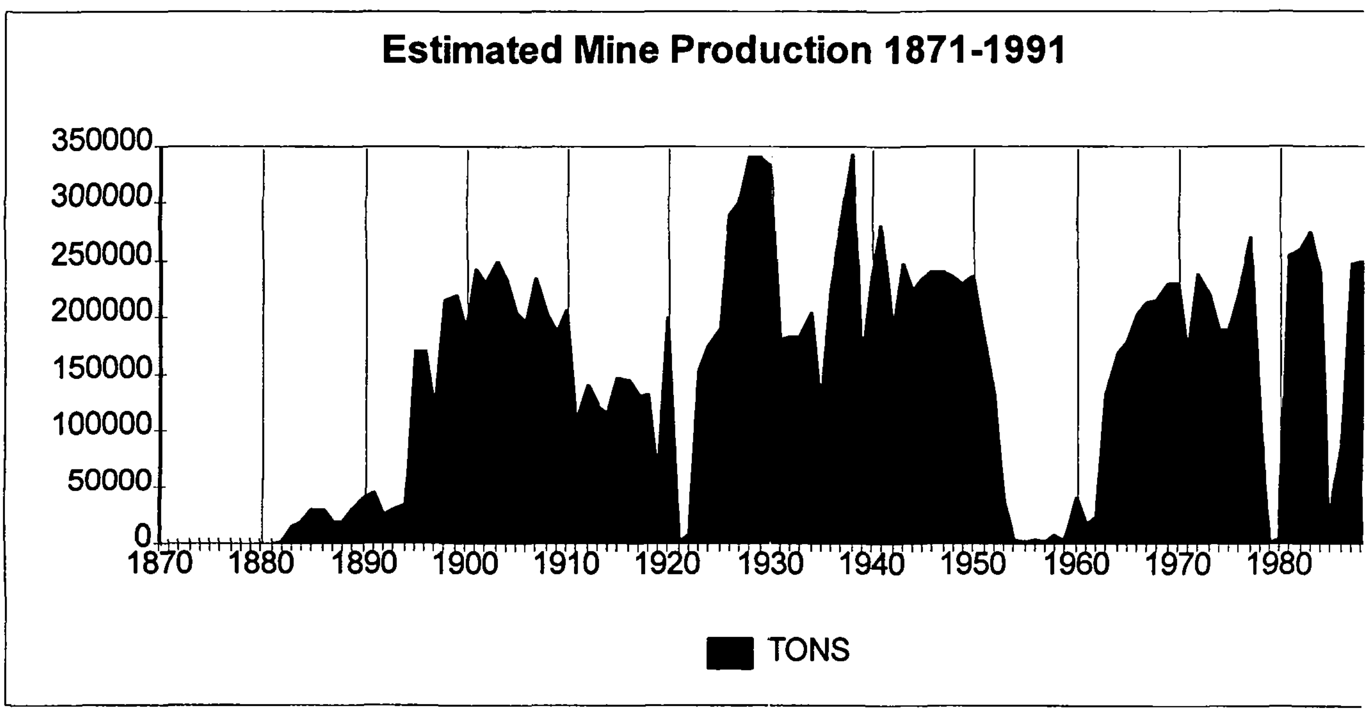
The tailings still were disposed of in the river. However, they were finer and carried farther. Farmers around Durango complained that they were filling in ditches and threatened lawsuits. Public attitudes towards mining and environmental degradation were changing.

By 1935, only one mill was operating in the Basin and it opted for a new disposal method – tailings ponds. This way water slowly filtered out and a much smaller proportion of metals reached the river. With the exception of a few pond failures, tailings were no longer dumped directly into the river. But the damage had been done. From 1890 to 1935, an estimated 7.5 million tons of tailings were discharged into the river. They may still be affecting water quality today.

After 1930, only two mines account for 90% of the Basin production, the Shenandoah-Dives (1930-1952) and the Sunnyside (1962-1991). During World War II, demand for base metals was so high, that many of the old waste rock piles were reprocessed, further removing metals from the Basin.

Figure 8-2 shows the estimated mine production levels in San Juan County. From 1900 to 1935, most of this material was dumped into the river in the form of tailings.

Figure 8-2



Source: Jones, 2000.

Another event of interest occurred in 1978. Miners in the Sunnyside came up below Lake Emma. Heat from the mine melted glacial ice under this high alpine lake and the bottom collapsed. An estimated 6 million gallons of water flushed down 1,400 vertical feet through the mine workings. The gray dirt and sediment changed the color of the Animas all the way to Farmington, over 100 miles away. Fortunately, it occurred on a Sunday, the only day when no one was working in the mine.

Sediment Studies

Two scientific sediment studies have documented some of the impact caused by activities described by Black and Jones. Vincent *et al.* (1999) (Appendix XX) report on findings in a trench dug across the valley floor of the Animas below Eureka, downstream from a number of historic mill sites. Church *et al.* (2000) (Appendix XX) examined metal content of pre-mining and post-mining sediments in a number of locations in the watershed. Both document substantial environmental changes caused by historic mining activities.

In 1998, a trench was excavated across the wide, flat Animas River floodplain downstream from the historic town of Eureka (upstream from Silverton). Mills above the site operated from the late 1880's to 1930. The exposed sediments were mapped and sampled. (Vincent *et al.*, 1999) The sediments were also dated using a number of methods. Buried artifacts from the early mining era were found. Growth rings were counted from old willow roots imbedded in the different sediment layers. Radiocarbon dating was used on roots and peat.

The overall deposition of sediments increased rapidly during the milling period. The authors estimate that sedimentation rates grew 50 to 4,700 times the natural sedimentation rate that might be expected. This was due to the practice of dumping huge quantities of mill tailings into the river.

Sediment samples were analyzed for vanadium and zinc. During the milling period, vanadium concentrations in the sediments dropped off drastically and zinc concentrations grew. The vanadium that was carried by naturally deposited sediments became diluted by the mill tailings. The tailings carried high levels of zinc. Zinc concentrations in the pre-mining sediments were an order of magnitude greater than the crustal abundance of zinc. But post-mining sediments had zinc concentrations another order of magnitude higher.

Church *et al.* (2000) studied sediments along the Animas from the Silverton area down to Durango. The team used geomorphological mapping of pre-mining sediment deposits. They cored and dated trees growing in deposits two meters above the current flood plain. The trees gave minimum ages for the deposits. Over 50 sites pre- and post-mining deposit sites sampled.

Metal concentrations for a number of elements increased dramatically between pre- and post-mining deposits. Concentrations for cadmium, copper, lead, silver, and zinc were as much as ten times greater in the more recent deposits.

Intense Water Sampling

While sediment data demonstrates the effects of historic tailings discharges into the river, it not very helpful for determining the relative loading caused by today's natural and human-related metal sources. One method for making this relative loading determination is to monitor all loading sources – draining mine adits, seeps and springs. This has been attempted in several small sub-basins in the upper Animas watershed during low flow conditions. (Wright and Nordstrom, 1999)

The largest sub-basin subject to intensive water sampling is the Middle Fork of Mineral Creek, an area subject to intense geologic alteration and little mining. This area was targeted specifically because of the large natural sources of metals. One small sub-basin of the Middle Fork, informally referred to as the Red Tributary, appears to have seen little if any mining, yet the stream carries very high concentrations of metals, especially aluminum. Dissolved aluminum concentrations were found greater than 50,000 ug/l. (Mast *et al.*, 2000) WQCC's Table Value Standard for chronic and acute toxicity for aquatic are 87 ug/l and 750 ug/l respectively

Using a mass-balance approach, two efforts were made to estimate the relative contributions of natural and mining loading sources for a number of metals for the Middle Fork. Some of the metals precipitate easily, making mass-balance calculations somewhat tenuous. Nevertheless, first study, conducted in 1995, found that 90% of the aluminum, 65% of the copper, 70% of the iron, 65% of the sulfate, and 35% of the zinc came from natural sources during low flow. (Wright, 1997) A later study using the same 1995 data plus summer low-flow samples from 1997 and 1998 low-flow data found that 90% of the aluminum, 82% of the copper, 66% of the iron, 72% of the sulfate, and 76% of the zinc came from natural sources. (Mast *et al.*, 2000)

Unfortunately, the Middle Fork watershed is less than 5% of the Basin, and it is difficult to carry these results over to other areas. The cost of a Basin wide study would be enormous. The method also fails to take into account if miles of mine workings may have altered the hydrology of certain areas to such a degree that natural conditions are no longer identifiable.

Some work has been done using oxygen isotopes of sulfate as indicators of whether or not the sources of water are natural or mining-related. (Wright and Nordstrom, 1999) Results of this work found the same percentage of sulfates stemming from natural sources in the Middle Fork Basin as the mass-balance approach. Work to refine this method of analysis is on-going.

Summary

Geology is one of the biggest factors in determining loading sources of metal in the Animas Basin. The geology is what attracted miners in the first place. Mining activities can exacerbate natural processes which create acid drainage and metal loading. The disposal of millions of tons of tailings directly into the river in the early 1900's undoubtedly affected water quality in the Basin.

The question of how much metal loading in upper Animas Basin is natural and how much is human related is still unanswerable. In certain locations, natural metal loading can be very substantial. The next chapter quantifies how much loading comes from identifiable sources and how much is unaccounted for.

References:

Black, Michael, *Historical Accounts of Water Quality in the Animas River Basin, 1878-1991*, June 1994, unpublished document.

Bove, D.J., M.A. Mast, W.G. Wright, P.L. VerPlank, G.P. Meeker, and D.B. Yager, "Geologic Control on Acidic and Metal-Rich Waters in the Southeast Red Mountain Area, near Silverton, Colorado," ICARD, 2000

Church, S.E., D.L. Fey, and Robert Blair, "Pre-Mining Bed Sediment Geological Baseline in the Animas River Watershed, Southwestern Colorado," ICARD, 2000.

Jones, William R., *History of Mining & Milling Practices &Production in the Upper Animas River Drainage 1871 – 1991*, Spring 2000, unpublished document.

Mast, M.A., P.L. VerPlank, D.B. Yager, W.G. Wright and D.J. Bove, "Natural Sources of Metals to Surface Waters in the Upper Animas River Watershed," ICARD, 2000.

Vincent, K.R., S.E. Church, and D.L. Fey, "Geomorphological Context of Metal-Laden Sediments in the Animas River Floodplain, Colorado," *U.S. Geological Survey Toxic Substances Hydrology Program- Proceedings of the Technical Meeting, Charleston, South Carolina, March 8-12, 1999*, Water Resources Investigations Report 99-4018A.

Wright, W.G., and D.K. Nordstrom, "Oxygen Isotopes of Dissolved Sulfate as a Tool to Distinguish Natural and Mining-Related Dissolved Constituents," *U.S. Geological Survey Toxic Substances Hydrology Program- Proceedings of the Technical Meeting, Charleston, South Carolina, March 8-12, 1999*, Water Resources Investigations Report 99-4018A.

Wright, Winfield G., *Natural and Mining-Related Sources of Dissolved Minerals during Low Flow in the Upper Animas River Basin, Southwestern Colorado*, U.S. Geological Survey, Fact Sheet FS-148-97, Oct. 1997.

SECTION 5: Existing Uses

Water quality classifications and standards are used to protect existing or practicably achievable uses and to establish criteria that will meet the fishable swimmable goals of the Clean Water Act. Colorado's approach is to establish use classifications and assign water quality standards, usually numeric criteria, to support those uses. Numeric criteria protect the most restrictive use. For example, standards for cadmium, copper, lead, manganese, and zinc are required for waters supporting both aquatic life and water supply uses. The aquatic life standards are more restrictive for all these metals except manganese. If these two uses are present, the aquatic life standards would be assigned for cadmium, copper, lead and zinc, but the water supply standard would be assigned for manganese. The use classifications assigned to surface waters in the upper Animas watershed are summarized in Table 5.1. The basis for assigning them are discussed in Section 5.

Table 5.1

Segment	*Description*	*Aquatic 1*	*Aquatic 2*	*Rec 1*	*Rec 2*	*Water Supply*	*Agric*
1	Weminuche Wilderness	X		X		X	X
2	Animas ab Maggie				X		X
3a	Animas ab Cement	X			X		X
3b	Animas ab Mineral				X		
4a	Animas ab Elk Creek	*	X	X			
4b	Animas ab Junction Ck	X		X		X	X
5a	Animas ab So. Ute	X		X		X	X
5b	Animas ab New Mexico	X		X		X	X
6	Upper Animas tributaries	X			X	X	X
7	Cement Creek				X		X
8	Mineral ab South Mineral				X		X
9a	South Mineral	X			X	X	X
9b	Mineral bl South Mineral	X			X		X
12a	Tributaries To 4a and 4b	X		X		X	X
15	Upper Cascade Creek		X		X	X	X

* Adopted as a goal

Aquatic Life

Aquatic life is classified as warm or cold and as class 1 or class 2. The distinction between warm and cold is whether or not the water temperature is suitable for trout (cold water fishery) or for warm water species. Surface waters in the upper Animas basin are classified cold water. Aquatic life class 1 streams have the physical characteristics (i.e. substrate, cover, and flow conditions) to support a wide variety of cold water biota. Suitability of habitat and water quality distinguishes class 1 from class 2 streams. Streams with insufficient flow, habitat, or water quality that is either naturally impaired or irreparably impaired by anthropogenic causes may be classified aquatic life 2. One approach for determining if improved water quality in a stream could lead to more diverse forms of aquatic biota is to compare the existing aquatic life in streams impaired by mining to that of unimpaired or reference streams. The reference streams must have the same basic geology and geography region. Comparison of streams unimpacted by mines but of naturally poor quality can be compared to those with some anthropogenic impacts to get an idea of potential for improvements.

Water quality investigations of the upper Animas Basin between 1991 and 1994 found that segments 1, 3a, 4b, 5a, 5b, 6, 9a, 9b, and 12a have the capability to fully support aquatic life class 1 uses (WQCD Exhibit 3, 1994). The 1994 water quality standards hearing and EPA's letter of April 1998 concluded that segments 2, 3b, 7, and 8 do not support aquatic biota and further are irreparably incapable of supporting even limited forms of aquatic biota. These segments have no aquatic life classification. Segment 4a is presently classified aquatic life 2 owing to high concentrations of metals. The WQCC adopted class 1 as a goal for this segment if sufficient improvement in water quality can be achieved. The purpose of this UAA is to determine if the water quality classifications and standards adopted in 1995 and disapproved by the EPA in 1998 will be achieved if anthropogenic sources of metal loading are remediated.

Segment 12a includes tributaries to the Animas south of Elk Creek. They are class 1. 12a should be revised to include all tributaries to the Animas River from the confluence with Mineral Creek to Baker's Bridge which are not included in segment 15.

Segment 6 should include all tributaries to the Animas River, from Maggie Gulch to immediately above the confluence with Mineral Creek that are not specifically identified in segment 6b.

A new segment 6b should be created for Arrastra Gulch and similar tributaries that have ambient quality exceeding TVS. The segment should initially be proposed class 2 aquatic life, based on ambient quality, unless there is information to support class 1. Ambient standards should proposed (EPA will not allow ambient standards if there is possibility for improvements--there is at Silver Lake although who knows how much it will improve things--but we cannot prove it won't. A company is currently trying to permit tailings removal and leaching of Silver Lake tails. Looks more like Aquatic 2 to me.. Alternatively, these tributaries could be made a part of 3a. If class 2 aquatic is proposed perhaps CDPHE will do the analysis to determine if class 1 or class 2 is most appropriate. Recreation class 2 should be proposed for the segment. There is no evidence of current water supply or agriculture uses of the segment.

Recreation

Recreation class 1 waters are used for activities in or on the water if the ingestion of small quantities of water is likely to occur. Recreation 1 activities may include, but are not limited to waters used for swimming, rafting, kayaking, and water skiing. Class 2 waters are suitable for use on or about the water such as fishing and other streamside or lakeside activities.

Water quality standards for class 1 and class 2 recreation waters are distinguished by the standard for fecal coliform. Recreation class 2 waters have a fecal coliform standard of 2000/100ml whereas class 1 waters have a standard of 200/100ml.

Most waters in Colorado are too shallow and/or too cold to support recreational class 1 uses. The quality of many of these waters is better than what is required for class 1, (i.e. concentration of fecal coliform is much lower than the class 1 standard). In order to maintain the bacterial quality of waters in Colorado the WQCC and U. S, Environmental Protection Agency agreed to classify waters recreation 1 only when they are used for recreation in or on the water. The class 1 standard for fecal coliform, however, is adopted for class 2 waters meeting the 200/100ml standard unless existing point source discharges would incur substantial costs to meet the 200/100ml standard. Streams used for rafting and kayaking include the Animas River from near Silverton to Tacoma (segments 4a and 4b) and the Animas below Baker's Bridge (segments 4b and 5a). Segment 3b, the mainstem of the Animas River from Cement Creek to the confluence with Mineral Creek is classified recreation class 2 and has the higher fecal coliform standard because the Silverton municipal wastewater treatment plant discharges to the segment. The Purgatory WWTP discharges to segment 15 which also has the higher fecal coliform standard.

Water supply

Waters with water supply classification are suitable for potable water after receiving standard treatment, filtration and disinfection. The water supply classification is applied if the quality is suitable for that use. Bear Creek and Boulder Creek, parts of segments 9a and 6, are the sources of Silverton's municipal supply. No other public water supplier uses the Animas or its tributaries in the UAA area until the river reaches Durango, segments 4b, 5a, 5b. Segment 15, which has an aquatic life class 2 classification, has metal standards adopted for water supply.

Agriculture

The agricultural classification is used for waters that are diverted for irrigation or that may be used for watering livestock. Sheep graze the headwaters of the Animas, Mineral, and Cement Creeks in the late summer and early fall. This is the only agricultural use of water in the upper basin. The Animas River from Silverton, the beginning of segment 3b to Baker's Bridge, is not used by domestic livestock, except for occasional pack animals. Irrigation and stock watering are common uses in the lower basin. Although agricultural uses are recognized in the classifications, no standards specific to agriculture are in place for the UAA segments.

DRAFT

SECTION 9: Existing Quality and Sources of Degradation

Many water quality standards for the Animas River basin changed as a result of the 1994 hearing. The changes, based on data collected between 1989 and 1994, reassessed the status of aquatic life and estimated the potential for establishing aquatic life in the Animas River and several of its tributaries. Several activities affecting water quality have occurred and new data has been collected since 1994. New data is to

quantify seasonal and annual variations in loading from identifiable mining related sources,

improve estimates of metal contributions from all other sources,

evaluate seasonal variations in water quality at the four gaging stations, and

evaluate water quality effect previously implemented remediation projects, has had on the chemistry of Mineral, Cement, and the Animas River.

These data, together with data from the earlier studies, will be used to establish water quality goals that may reasonably be achieved through restoration of disturbed sites. Alternative uses and standards that might be achieved through remediation are proposed. The UAA focuses on stream segments with aquatic life classifications and standards disapproved by EPA in their letter of September 1998 or which are contained in the state's 1998 303(d) list. The list of stream segments that do not comply with the state's 303(d) list and EPA's 1998 disapproval letter are shown in Table 9.1

In-stream water quality

Procedures for evaluating water quality and establishing standards have been adopted by the Colorado WQCC. Existing or ambient water quality is compared to Table Value Standards (TVS). The regulation defines ambient quality as the 85th percentile of representative data. If it is shown that ambient quality is better than TVS for the classified use, TVS are adopted ("The Basic Standards and Methodologies for Surface Water"). TVS for Cd, Cu, Pb, Mn, and Zn vary with water hardness. Higher metal concentrations are tolerated at higher hardness values. The practice of the WQCD has been to compare TVS using average hardness values with 85th percentile concentrations.

Ambient standards, 85th percentile, may be adopted if natural or irreversible man-induced constituent concentrations are higher than the specified chronic TVS, but the use is present. The EPA disapproved the ambient standard for zinc adopted by the WQCC for segments 3a, 4a, and 9b. They also disapproved the ambient standards for copper and iron in 9b.

Site-specific standards, acute or chronic, may be used for aquatic life segments where factors other than water quality substantially limit the diversity and abundance of species present. Site specific standards require a use attainability assessment to support such standards. The site specific approach was used for Zn in segment 4a, however that standard was also disapproved by EPA.

Table 9.1 Stream Segments Shown on CDPHE 1999 303(d) list

<date>

DRAFT Segment	Description	Use Impaired	Constituent(s)
2	Animas above Eureka	Metal source	Al, Cd, Cu, Fe, Pb
3a	Animas Eureka to Cement Ck	Aquatic life	Zn*
3b	Animas, Cement Ck to Mineral Ck	Metal source	Al, Cd, Cu, Fe, Pb
4a	Animas, Mineral Ck to Elk Ck	Aquatic life	PH, Cu, Fe, Zn*
4b	Animas, Elk Creek to Junction Ck	Aquatic life	Zn
7	Cement Creek	Metal source	Al, Cd, Cu, Fe, Pb
8	Mineral Creek above So. Mineral	Metal source	Al, Cd, Cu, Fe, Pb
9b	Mineral, So. Mineral to Animas	Aquatic life	PH, Cu*, Fe*, Zn

* Standards were disapproved by EPA on August 27, 1998

Narrative standards (Section 3.1.7(1)), may be applied if numeric standards are inappropriate. This provision was used for segments 2, 3b, 7, and 8 owing to natural sources of acid and metals that prevent attainment of aquatic life uses. Reduction of man-induced sources from these segments, however, is critical to the achievement of goals in downstream segments. The WQCC adopted and the EPA approved narrative standards for segments 2, 3b, 7, and 8.

Two methodologies are used to evaluate water quality in this UAA. The first is the 85th percentile methodology utilizing average hardness for those constituents whose TVS are a function of hardness. We use this method in order to be consistent with CDPHE practice. The second methodology eliminates the variation in concentration due to stream flow and seasonality which are the variables that account for most of the observed variation in concentration of constituents in surface water. This method also allows for evaluation of toxicological thresholds if hardness is added. We use this method to identify season, flow states, and duration of concentration which may impair classified uses.

Leib (2000) developed the water quality model for several mainstem and tributary segments in the upper Animas basin. The model uses discharge and season as the independent variables. Periodic functions describe seasonality using day of the year. A dummy variable, as in analysis of covariance, was used to test if remediation had altered water quality. If the model retains the dummy variable, $t_{\alpha/2} < 0.05$ for pre- post- remediation, it is concluded that there has been a change in water quality. This approach is described in Helsel and Hirsch, 1995. Year round monitoring at the gaging stations began in 1995, thus there is at least two years of pre-remediation data. The Leib model accounts for 12 to 86 percent of the variation (R^2) in constituent concentration. The highest R^2's are for hardness, Al, and Zn while the lowest is for Cd. Figure 9.1 shows the sites that were used to develop the model.

Table 9.2 includes data for the most recent three years, 1997 through 1999. These years correspond to the time period when several activities to improve water quality, including the Sunnyside Consent Decree and other remediation activities, began in the upper Animas, Cement, and Mineral Creek by SGC, the ARSG, and BLM. Table 9.2 compares the 85th percentile of representative water quality data for the UAA segments to the current standards and temporary modifications. Segments 2, 7, and 8 have narrative standards, therefore ambient conditions (85th percentile) that existed through 1994 are compared to water quality for the 1997 to 1999 period.

The concentrations in Table 9.2 were evaluated at four gaging stations and five secondary locations shown in Figure 9.1. The gaging stations have operated continuously since October 1, 1993 and are the most intensively sampled. The USGS collected monthly chemistry and flow data at the secondary stations during 1998 and 1999 to characterize the effect of stream flow and season on water quality at intermediate points for selected reaches. The secondary stations also establish baseline quality conditions that may be used to evaluate the effect of future remediation projects.

Table 9.2 shows the 85th percentile of Al, Cd, Cu, Fe, Mn, and Zn since October 1996 has increased in some cases. Higher levels are due to intensive monitoring during the winter period when stream flow is low and concentrations are higher. This is a better reflection of how the hydro-chemical system in the basin operates, not degradation of water quality. Very little winter data, except at A72, existed prior to 1995. Al was sampled only in the summer prior to 1995 at any location.

Segment 2

Some remediation has occurred in the headwaters of Segment 2, however water quality has generally remained the same at A33, the Animas River above Eureka, since 1994. Although there are differences in Cu and Zn as shown by the 85th percentiles, there is insufficient data to determine whether or not water quality has changed. Cd, Cu, and Zn remain above TVS for aquatic life.

Table 9.2a Comparison of ambient quality to TVS and adopted standards for Segment 2.

Site		pH	Al	Cd	Cu	Fe	Pb	Mn	Zn
	TVS				Not Applicable				
All	'91-'94	6.9	100	2.9	16		Bdl	800	700
A33	'98-'99	6.5	8	2.9	30	Bdl	Bdl	780	550

Segment 3a

The data at A 53 and A 60, the Animas River at Howardsville and below Arrastra Gulch respectively, in segment 3a shows a reduction in Cd, Cu, Mn, and Zn concentrations from segment 2. The dissolved Zn at these two locations is among the lowest in the basin. The higher Al at A 60 is due to more data collected during the winter low flow period. The concentration of Cd, Cu, Mn, and Zn greatly increases in segment 3a between Arrastra Gulch and Silverton at A68. The data from A 68, the most intensively sampled location on the segment shows levels of Al, Cd, Mn, and Zn are higher than the adopted standards.

Comparison of seasonally and flow adjusted concentrations of Cd, Cu, and Zn to pre-1997 data reveals no change in the concentration. The regression model suggests Mn concentration has increased since 1997. Higher concentrations of Cd, Cu, and Zn are the result of more data collected during the winter low flow and first flush periods. Figures 9.2 through 9.5 compare ambient concentration of Cd, Cu, Mn, and Zn to TVS using flow based hardness. Cd, Cu, and Mn exceed TVS for a three to four month period in the winter. Zn exceeds TVS year a round. Zn exceeds the ambient standard adopted by the WQCC during most of the winter period.

Table 9.2b. Comparison of ambient quality to TVS and adopted water quality Standards in segment 3a.

Site		pH	Al	Cd	Cu	Fe	Pb	Mn	Zn
	TVS	6.5	87	1.0	11		3	1000	95
All	WQS	**6.5**	**87**	**1.7**	**11**	**132**	**3**	**1000**	**540**
A53	'97-'99	**7.0**	**83**	**2.1**	**4**	**54**	**Bdl**	**262**	**304**
A60	'97-'99	**6.6**	**150**	**2.4**	**5**	**Bdl**	**Bdl**	**214**	**277**
A68	'97-'99	**6.2**	**115**	**3.0**	**9**	**120**	**Bdl**	**2500**	**900**

Segment 7

The data from Cement Creek at Silverton, CC 48, shows that there has been a significant, $p<0.05$, reduction in the levels of Cd, Mn, and Zn since SGC began treating the flow of Cement Creek from above the American Tunnel in October 1996, figures 9.6 to 9.9. SGC treated most or all of the flow of Cement Creek above the American Tunnel except during the four high flow months when the stream flow exceeded the capacity of the treatment plant (Larry Perino, personal communication). The average Mn level, as determined by the flow/seasonally adjusted methodology, has been reduced even though the 85th percentile suggests an increase. Treating the flow of Cement Creek did not change the levels of Al, Cu, or Fe at Silverton, CC 48, figures 9.10 and 9.11. Levels of Al, Cd, Cu, Pb, and Zn remain acutely toxic to aquatic life in Cement Creek. Treatment of Cement Creek will end after SGC completes their obligations under the Consent Decree.

Table 9.2c. Comparison of ambient quality to TVS and adopted water quality Standards in segment 7.

Site		pH	Al	Cd	Cu	Fe	Pb	Mn	Zn
	TVS			Not applicable					
All	'91-'94	4.4	4300	5.4	110		20	1500	930
CC48	'96-'99	3.8	3164	2.3	84	4823	13	1824	817

Segment 8

Partial remediation at the Kohler-Longfellow and Carbon Lakes sites near Red Mountain Pass has reduced the levels of Cd, Cu, Pb, and Zn in segment 8, Mineral Creek above South Mineral Creek (M27). The effect of the remediation is noted in both the 85th percentile and flow/seasonally adjusted methodologies. The Middle Fork of Mineral Creek, downstream from the Kohler-Longfellow, is the main source of Al and Fe, so little reduction of these metals due to remediation is seen at in Mineral Creek above South Mineral at M27. Concentrations of Al, Cu, Pb, and Zn remain at levels acutely toxic to aquatic life in segment 8.

Table 9.2d. Comparison of ambient quality to TVS and adopted water quality Standards in segment 8.

Site		pH	Al	Cd	Cu	Fe	Pb	Mn	Zn
	TVS			Not applicable					
All	'91-'94	4.5	5200	3.2	190	6900	23	860	920
M27	'97-'99	4.3	5500	1.8	112	4417	6.6	783	

Segment 9b

The 85th percentile methodology shows that Al exceeds acute criterion (750 ug/l) for aquatic life at M34, Mineral Creek near Silverton. Cd, Cu, and Zn exceed chronic TVS, however they are equal to or lower than the temporary modifications adopted by the WQCC in 1995. The regression model, figure 9.12, shows that the level of Al is elevated for over four months during the winter. Cd exceeds TVS during the spring runoff, figure 9.13. Cu and Zn exceed TVS most of the year, figures 9.14 and 9.15. The benefits of partial remediation at Kohler-Longfellow and Carbon Lakes are measurable in Mineral Creek, at M 34. Cu and Zn levels are lower than the adopted temporary modifications. The regression model shows an average reduction in Cu and Zn of 11 and 98 ug/l, respectively, at M34.

Table 9.2e. Comparison of ambient quality to TVS and adopted water quality Standards in segment 9b.

Site		pH	Al	Cd	Cu	Fe	Pb	Mn	Zn
	TVS	6.5	87	1.4	15		7	1000	137
	WQS	6.5	87	1.7	57	3415	7	1000	544
M34	'97-'99	4.8	2097	1.6	49	3300	2	471	482

Segment 4a

Monitoring at A 72, the Animas River below Silverton, segment 4a, shows levels of Al, Cd, Cu, Fe, Mn, and Zn exceed water quality standards using the 85th percentile methodology. Comparing pre 1997 data with post 1997 data using the flow seasonal adjustment regression methodology shows the water quality has not changed over the 1991 to 1999 period. The higher levels of Al, Cu, Fe, Mn, and Zn are due to more data collected during the winter spring flush periods. The regression model shows Cd and Cu slightly exceed chronic TVS during portions of the year, figures 9.16 and 9.17. Al exceeds the chronic criterion for aquatic life for most of the winter, figure 9.18. Zinc exceeds the chronic TVS year a round and exceeds the temporary modification adopted by the WQCC during the winter.

Table 9.2f. Comparison of ambient quality to TVS and adopted water quality Standards in segment 4a.

Site		pH	Al	Cd	Cu	Fe	Pb	Mn	Zn
	TVS	6.5	87	1.2	13		5	1000	117
	WQS	6.5	87	1.6	13	390	5	1000	520
A72	'97-'99	5.8	554	2.0	20	2326	Bdl	1600	723

Segment 4b

Dissolved Cd, Cu, Pb, and Zn, in segment 4b as measured in the Animas River at Baker's Bridge, A75, are lower than the adopted standards. This may be a reflection of remediation activities undertaken since October 1996.

Table 9.2g. Comparison of ambient quality to TVS and adopted water quality Standards in segment 4b.

Site		pH	Al	Cd	Cu	Fe	Pb	Mn	Zn
	TVS	6.5	--	1.6	17		7	50	149
	WQS	6.5	--	1.6	17	300	7	210	182
A75	'97-'98	7.5	--	0.5	Bdl	--	Bdl	326	157

Summary

The higher than expected concentrations of dissolved Al and Zn in segments 3a, 4a, and 9b are the result of more intensive monitoring during the winter low flow and first flush periods. Samples obtained during these times since 1995 clearly shows variations in water quality related to stream flow and seasonal factors that were not accounted for when the 1994 goals were set.

Table 9.3 85th percentile by season--December-May and June-November

		PH	*Al*	*Cd*	*Cu*	*Fe*	*Pb*	*Mn*	*Zn*
3a	Su	6.4	70	1	5	120	Bdl	1100	420
	Wi	6.1	133	4.5	10	120	Bdl	3400	1179
4a	Su	6.1	80	.0	8.3	895	Bdl	1070	430
	Wi	5.5	752	2.3	21	2749	1.0	1960	752
9b	Su	6.1	88	0.4	7	1760	Bdl	310	239
	Wi	4.8	2568	1.8	54	3700	1.4	542	530

Higher concentrations of Al, Cd, Cu, and Zn per unit of discharge occur in the late winter early spring than at other times of the year. Zinc concentration elevates during the winter base flow period, peaking from around April 15 to the end of May at the start of the runoff period. Al concentration exceeds chronic criteria for aquatic life in segments 3a, 4a, and 9b from December through May and exceeds acute standards in segments 4a and 9b for the same time period. Cu concentration exceeds chronic TVS in segments 4a and 9b during the runoff period. Zn exceeds acute and chronic criteria in all three segments most of the year.

Assessment of sources

The water quality of the upper Animas reflects the combination of natural and man induced factors. Geologic processes that formed the San Juan caldera and subsequent circulation of fluids rich in sulfur and base metals provided the basis for the acid environment that exists today. Bove and others (2000) describes the area as being similar in nature to the acid-sulfate hydrothermal systems found in the Summitville and Lake City areas of Colorado. Oxidation of pyrite, the most widespread sulfide mineral, causes acid water, but contributes little in terms of base-metal content. Dissolved Cu and Zn originate from the oxidation of vein and disseminated base-metal sulfides, i.e enargite and sphalerite, (Bove and others, 2000). Aluminum is dissolved as a product of acid weathering of aluminosilicate minerals. Acidicwater, created from pyrite oxidation, increases the dissolution of all metals. Furthermore this acidic environment is ideal for acid loving bacteria (e.g. ..) that greatly increases dissolved metal concentrations while further lowering acidity through a biocatalytic process know as Acid Rock Drainage.

Early miners following veins that had been filled with sulfur and metal bearing fluids, exposed sulfide bearing minerals to oxygen in adits, stopes, and shafts. Exposure of sulfide minerals to oxygen whether through mine water or from dumps or mill waste is one of the processes leading to acid formation. When the acid waters come into contact with Al, Cd, Cu, Pb, and Zn minerals they dissolve and are transported to the streams. One of the challenges is to separate sources of acid and metals that are natural from those that have been aggravated by man's activities which might have the potential for remediation (i.e. "reversible").

Mine Related

Water quality investigations by the ARSG, including CDPHE, USGS, USFS, BLM, Sunnyside Gold Corporation, and other private interests, have investigated the sources of loading (discharge plus concentration) of various metals in the basin. Mine related sources include mine water from adits and shafts, waste dumps at the mine portals, and mill tailings. Over 120 adits within the upper basin have been sampled one or more times. Table 9.3 summarizes some of the important load characteristics of these studies. The American Tunnel on Cement Creek near Gladstone, historically was the largest source of load. Drainage from the American Tunnel has been treated since 1989. The tunnel was partially bulkhead sealed in late 1996, and is scheduled for complete closure in accordance with the Sunnyside Consent decree. Several other adits, including the Terry Tunnel (1996), Ransome adit (1998) on Eureka Creek, and the Sunbank (1993) and Gold Prince (1997) adits near the Animas headwaters have been sealed since investigations began in 1991.

Although the discharge of mine water tends to be relatively constant over the year, seasonal variation in the discharge rate in some mine water has been observed. One of the objectives of the ARSG, USGS, and SGC is to establish the variation in load over the annual cycle. This will be used to identify the more significant adits and to quantify the potential for lowering the in stream concentration by controlling mine water as it relates to seasonal variation in stream flow.

Waste rock from the mining process is a second source of metals. Waste rock includes dump material deposited near mine workings and mill tailings. Waste rock (dumps) at the mine sites are highly variable in their acid and metal producing capability. Waste rock from mine workings driven through non sulfide bearing minerals have little acid producing potential. Mill tailings, generally speaking, have the greatest acid generating capability because the rock is finely ground which exposes more surface area to oxidation. Moreover, rock transported to the mills were the major ore bearing minerals such as pyrite, sphalerite, galena, and enargite which have the richest metal content and the highest acid generating potential. Early mill technology often left large quantities of these base metals in the tailings, concentrating on recovery of the precious metals, gold and silver.

The potential for metal loading from dumps and mill tailings is greatest in the spring during snowmelt and from late season thunderstorms. Melting snow infiltrates and percolates through the waste piles recharging shallow ground water or directly runs off to nearby streams. Late season thunderstorms also increase metal loading from waste rock areas. Wirt and others (2000) measured the load of Al, Cd, Cu, Fe, and Zn from Prospect Gulch during a September thunderstorm, and found them to be one or more orders of magnitude higher during storm runoff conditions than during base flow. They also found the largest increases in loads corresponded to areas where waste-rock dumps were in close proximity to the stream.

Mill tailings have been consolidated to several areas along the Animas River mostly within segment 3a. Mill tailings at the Mayflower Mill (Ponds 1-4)have been capped and revegetated in accordance with Sunnyside's mine reclamation plan. SGC also removed historic mill tailings from Howardsville to their tailings pond number 4 near Silverton in 1997.

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Mill tailings, from the South Fork of Cement Creek, were relocated to tailings pond #4 between 1990 and 1992. Analysis of data collected by SGC has shown that relocation of this pile resulted in a measureable decrease in the dissolved aluminum and dissolved iron concentration in South Cement Creek.

Extensive investigations of over _____ waste dumps by the DMG, USFS, BLM, ARSG, and Sunnyside since 1995 have identified the most significantly impactingdumps. Two dumps identified through the ARSG process have been partially remediated. Sunnyside covered and amended the Longfellow dump and relocated the Kohler dump on Red Mountain Pass in 1996-97. The ARSG, with the assistance of a Sec. 319 non point source grant, is currently relocating the dump at nearby Carbon Lakes to Pond #4 as well. Remediation of these three sites has resulted in a measurable reduction of dissolved cadmium, copper, and zinc in Mineral Creek at Silverton.

Other human impacts:

Failure of a large tailings pond at Eureka during a flood in the 1930's caused tailings to be deposited over a large area of the flood plain of the Animas River. Sediment movement in this reach of the Animas has caused the channel to aggrade , raising the base of the streambed by about one meter, since mining began(Vincent, 1999). The result of the aggradation was to obliterate the pre-mining morphology of the stream and destroy the willows that provided bank stability and riparian habitat (Milhous, 1999). Much of the tailings have been transported downstream and incorporated into stream sediments. SGC removed much the remaining consolidated tailings from terraces near the Animas River at Eureka in 1997. Church and others (1997) found concentrations of Pb, Zn, and Cu in bed sediments of the upper Animas River were four to six times higher than concentrations found in pre-mining bed sediments.

Other human activities in the basin have the potential to impact water quality. Roads used to reach the mine sites and for recreation are potential sources of sediment. . Alpine sections of the headwaters of the Animas, Mineral, and Cement Creeks have grazing allotments for sheep. Accelerated erosion of soils formed from decomposed sulfide minerals due to overgrazing is a potential source of metal and sulfide laden sediment.

The town of Silverton WWTP discharges to the Animas River above Mineral Creek. The ARSG sampled several sewer lines in town. Cadmium, copper, lead, manganese, and zinc were all found, however concentrations were lower than concentrations found in the River. The wastewater treatment plant is not a significant source of metals.

Groundwater

Groundwater as a source of metals to the Animas River and its tributaries was minimally evaluated before 1996. Recent investigations have shown that groundwater is a major cause of acid and metal loading. Loads from groundwater can be both natural and man induced. Identified sources include natural springs, fractures and faults, and movement of water through waste-rock.

Investigations of Mineral Creek and Cement Creek (Wright, 1999) identified large quantities of Al and Fe in springs from areas that are not affected or only minimally affected by mining. A large natural spring in the Middle Fork of Mineral Creek (M18) is the biggest contributor of dissolved Al and Fe to Mineral Creek. The Paradise Portal, a short distance upstream from the spring is the second largest source of dissolved Al and Fe to Mineral Creek. This shallow portal was probably abandoned due to the large volume of water encountered. Springs emanating from shallow prospects, such as the Ferrocrete and Imogene mines, in the Mineral Creek watershed, are large sources of Al and Fe. Tracer-injection studies by the USGS in 1997 found that the summation of the Zn load from tributary and mine sources was substantially less than the total load in three discrete reaches of Cement Creek where ground water inflow entered the stream along fractures (Kimball and others, 2000). High in the headwaters of the Animas watershed stream channels in Burrows and California Gulches, follow mineralized fractures and faults. Large increases in manganese and zinc loads not associated with surface expression of mining were noted in these areas (Herron and others, 1998).

Shallow wells, were driven into in the gravel in and around Silverton in order to obtain ground water samples that reflected the Animas, Cement and Mineral Creek flow regimes, Ground water from these wells showed varying concentrations of cadmium, copper, lead, manganese, and zinc. The highest concentrations of manganese and zinc, 66,000 and 7000 ug/l respectively, were found at the Silverton campground near the north end of town. The well at the Silverton campground is upstream from A68 and groundwater from this plume probably has an effect on the level of metals measured at A68. Zinc concentration averaged 385 ug/l in the well near the WWTP at the south end of town.

Load Analysis by Segments

One of the goals of the ARSG is to identify sources of metal loading and to estimate the water quality that would result if a number of sources were controlled. This estimate of attainable water quality would be used to judge the aquatic life that could be supported.

Data have been collected to estimate loads from adits, mine waste, natural springs, groundwater and other sources. These loads have been compared to loads in various segments of streams in the basin on a synoptic, seasonal, and annual basis. One important conclusion from the studies is that significant attenuation of some metals from the source to where they are measured downstream (reference).. Dye tracer synoptic studies done by the USGS in 1997, 1998, and 1999 demonstrated that the sum of measured loads is greater than what is measured at the four gaging stations. Two chemical processes, precipitation and sorption contribute to the attenuation (reference). The order of attenuation of target metals in the Animas basin from greatest to least are Pb, Al, Cu, Fe, Zn, Mn, and Cd.

Metals found in waters with low pH are mostly dissolved. Increasing the pH causes the metals to precipitate. The pH at which this occurs is different for each metal. Al, Cu, Fe, and Pb are among the first metals to precipitate, while Cd, Mn, and Zn require higher pH. The pH of Cement Creek (4.4 to 5.1) is low enough to keep most metals (except Pb) in the dissolved form. This is also largely true for Mineral Creek, especially during the winter months when the mean pH is 5.0. The pH of the Animas River on the other hand (6.5 to 7.8) is high enough to cause precipitation of all metals except cd, mn, and zn.

Recent laboratory studies by the USGS (Schemel and others, 1999) demonstrated that the fraction of Zn in the colloidal phase (precipitate) increases with increasing pH. Moreover, their laboratory studies showed that a greater fraction of zinc was in the colloidal phase when associated with high concentrations of Al and Fe colloids. The colloids are available for precipitation or coprecipitation. Schemel and others (1999) suggest that the natural mixing of Cement and Mineral Creek waters high in Al and Fe colloids waters with higher pH waters from the Animas may result in significant sorption of zinc onto Fe and Al colloids. This process of trace metal sorbtion likely occurs where ever the combination of waters rich in iron, aluminum, and trace metals are subjected to waters with less acidity.

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Animas

Mining related (no distinction made between reversible and irreversible, see section XII)
Adits
Dumps
Mill tailing and smelter slag
Other sources – roads, grazing, Silverton W.W. plant, stormwater load
Groundwater
Other unindentified sources including natural
(potentially use some site specific examples of

Cement

Mining related (no distinction made between reversible and irreversible, see section XII)
Adits
Dumps
Mill tailing and smelter slag
Other sources – roads, grazing, Silverton W.W. plant, stormwater load
Groundwater
Other unindentified sources including natural
(potentially use some site specific examples of

Mineral

Mining related (no distinction made between reversible and irreversible, see section XII)
Adits
Dumps
Mill tailing and smelter slag
Other sources – roads, grazing, Silverton W.W. plant, stormwater load
Groundwater
Other unindentified sources including natural
(potentially use some site specific examples of

Figures 9.2 to 9.5

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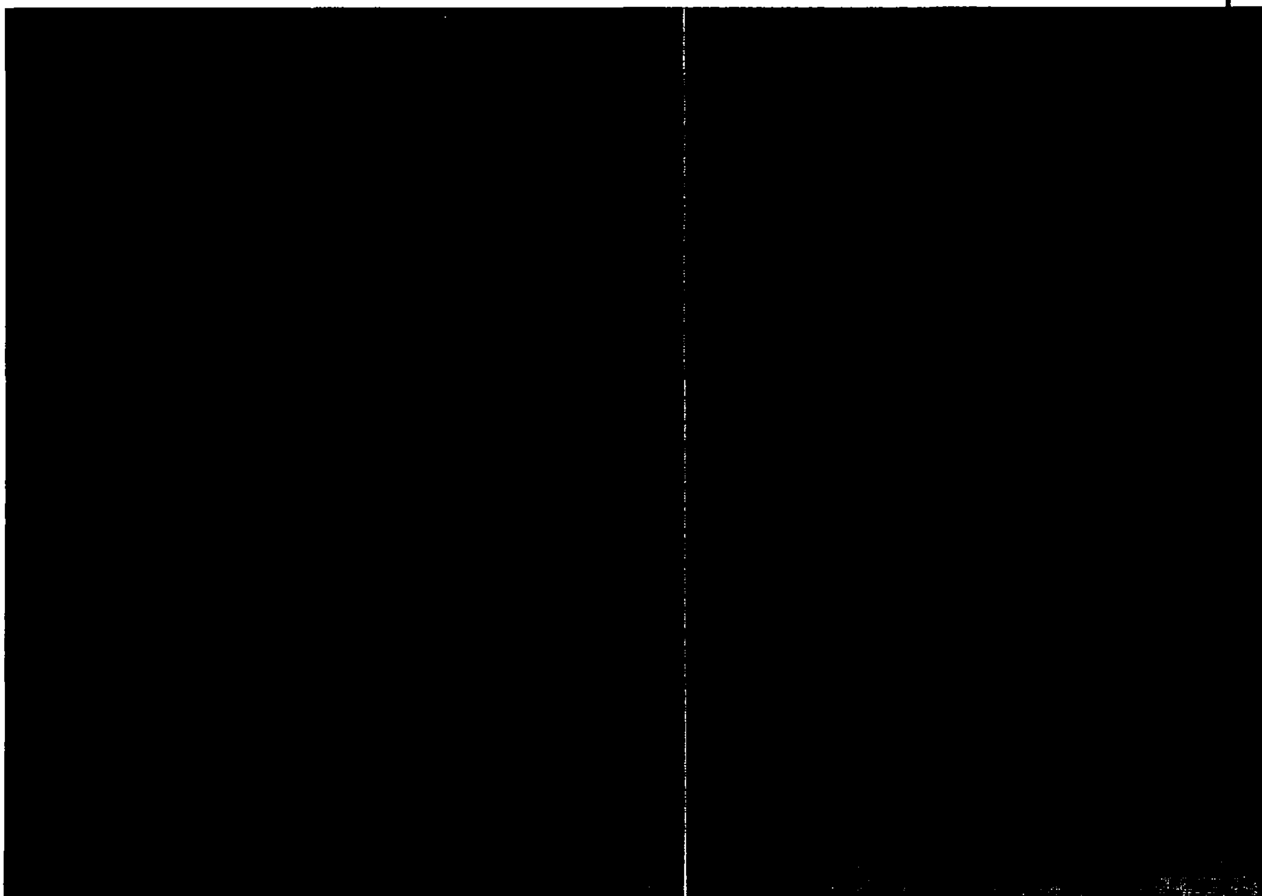

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Figures 9.6 to 9.11

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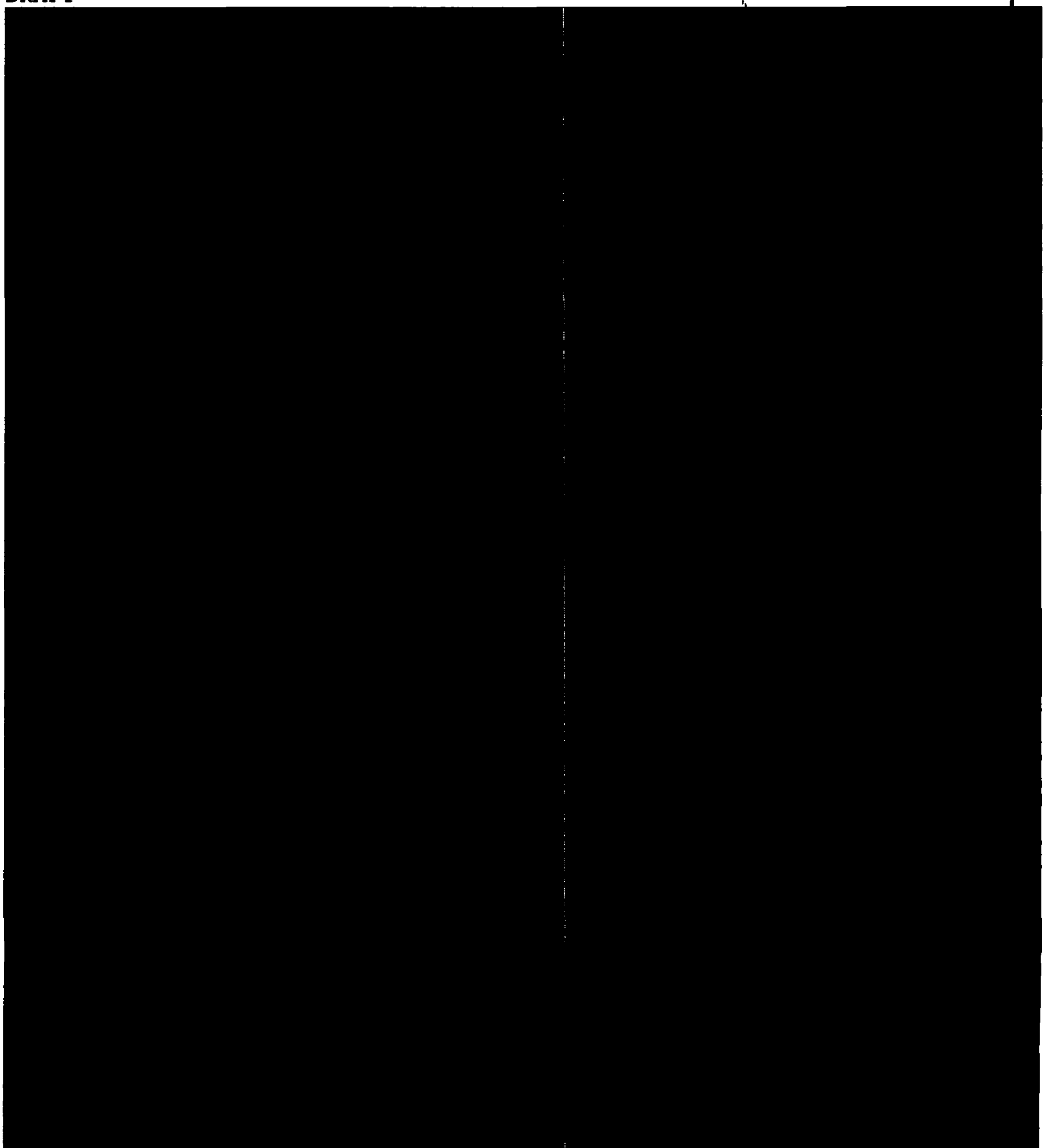

Figures 9.12 to 9.17

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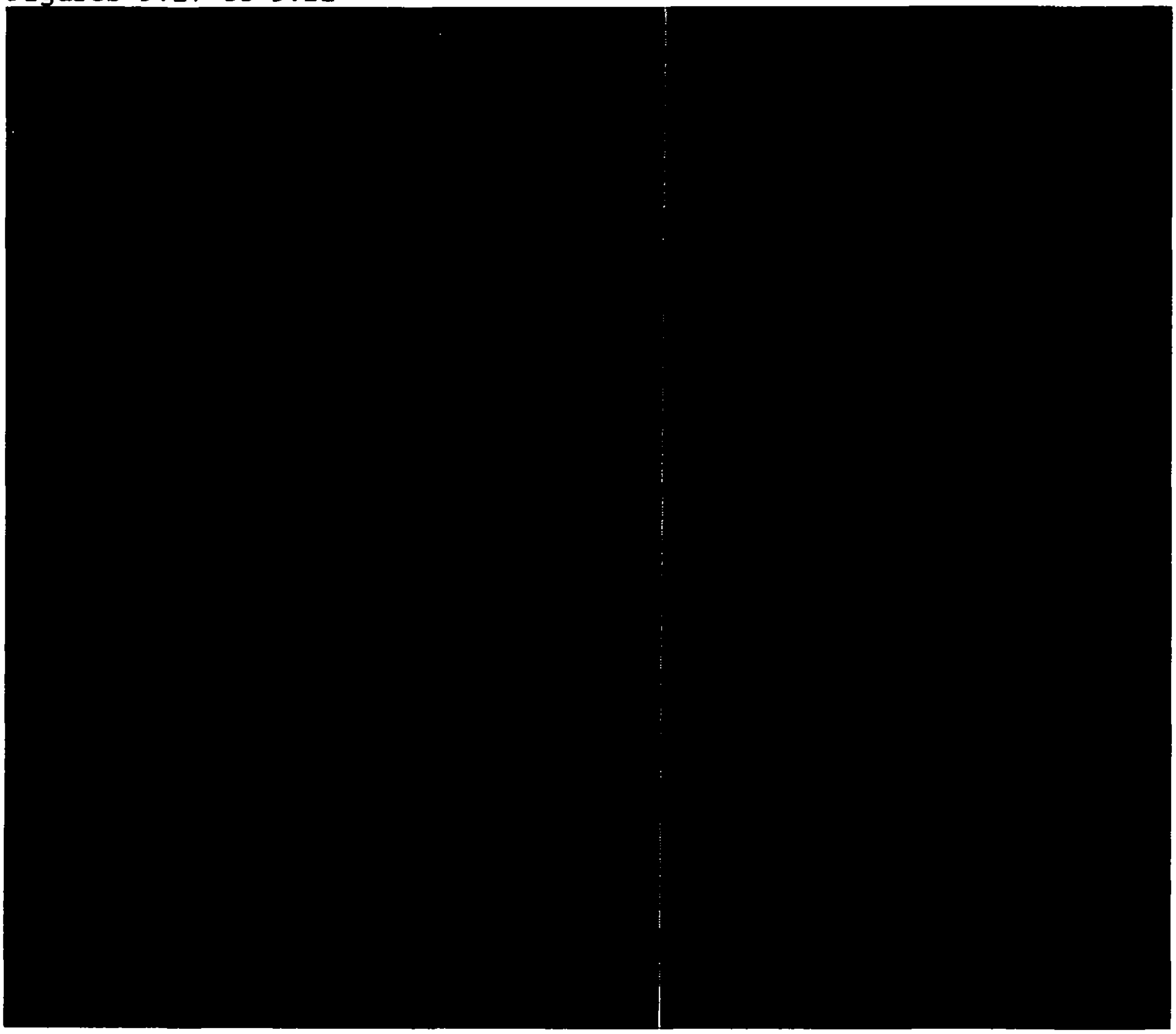
Figures 9.17 to 9.21



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